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Abstracts

SEISMIC VULNERABILITY OF THE SACRAMENTO-SAN JOAQUIN DELTA LEVEES

N.A. Abrahamson[1], F.N. Brovold[2], G. Cosio[3], M.W. Driller[4], Leslie F. Harder*[4], N.D. Marachi[5], C.H. Neudeck[6], L.M. O'Leary[7], M. Ramsbotham[7], R.B. Seed[8], and R.A. Torres[4]

[1]**Consulting Seismologist**

[2]**GEI Consultants**

[3]**MBK Engineers**

[4]**California Department of Water Resources, 1416 Ninth Street, Sacramento, CA 95814, Phone: 916-653-3927, Fax: 916-657-2467, e-mail: harder@water.ca.gov**

[5]**Consulting Geotechnical Engineer**

[6]**Kjeldsen, Sinnock & Neudeck, Inc.**

[7]**U.S. Army Corps of Engineers and CALFED**

[8]**Seismic Geotechnical Consultant**

This report, prepared by the Seismic Vulnerability Sub-team of the CALFED Levees and Channels Technical Team, provides an assessment of the current vulnerability of levees in the Sacramento-San Joaquin Delta to damage that may be induced by future earthquakes. The seismic risk analyses and assessments that were carried out were based on the most current available information. Earthquake models both with and without a major blind thrust fault zone through the western Delta were considered in the evaluations.

This study subdivided the Delta into four Damage Potential Zones. Seismic vulnerability was estimated by combining a probabilistic assessment for various earthquake motions (loading) with the estimated seismic fragility (resistance) of different levee reaches. Seismic vulnerability is highest in Zone I, Sherman Island, due to poor levee embankment and foundation soils, and a higher exposure to seismic shaking at the western edge of the Delta. Zone II, the central area of the Delta, has the next highest overall level of seismic levee fragility and exposure to seismic shaking. Zones II and IV, with levees of lower heights more distant from earthquake shaking, have generally lower levels of seismic vulnerability.

The study predicts that an earthquake with a 100-year return period is likely to cause 3 to 10 levee failures on one or more islands. However, a stronger earthquake with a return period of 300 years might result in up to 40 levee failures.

RECIPROCAL HYBRIDIZATION AND THREAT OF INVASIVE *SPARTINA* TO SALT MARSHES IN THE SAN FRANCISCO ESTUARY

Debra R. Ayres[*] and D.R. Strong

Evolution and Ecology, 1 Shields Ave., University of California, Davis, CA 95616,
Phone: 530-752-6852, e-mail: drayres@ucdavis.edu

Spartina alterniflora, endemic to the eastern U.S., was introduced into the range of a native congeneric species in south San Francisco Bay ca. 25 years ago. Using RAPD markers and chloroplast DNA, we determined that extensive hybrid swarms have arisen through reciprocal hybridization. Native *S. foliosa* was virtually absent in salt marshes where *S. alterniflora* was deliberately planted; we found roughly equal numbers of S. alterniflora and hybrid individuals. We examined a wide range of genetically characterized individuals for morphological, sexual, and flowering traits. We found positive correlations between increasing contributions from the *S. alterniflora* genome and plant size, number of spikelets, pollen abundance and viability, and seedling growth. Seed set and germination of hybrids were lower than those of the parental species; however, these losses were offset by the greater numbers of spikelets produced by hybrids. In the field, there was little temporal overlap in flowering between the 2 species, and we found no F1 hybrids. Hybrids bridge the phenological gap. Robust hybrids, producing copious pollen and seed coincident with the flowering of *S. foliosa*, could prove to be an even greater menace to *S. foliosa* and estuary ecosystems than *S. alterniflora*.

BIOACCUMULATION OF SELENIUM BY PHYTOPLANKTON

Stephen B. Baines* and S.F. Nicholas

**Marine Sciences Research Center, SUNY Stony Brook, Stony Brook, NY, 11794-5000,
Phone: 631-632-3128, Fax: 631-632-8820, e-mail: sbaines@ms.cc.sunysb.edu**

Assimilation of dissolved Se by phytoplankton is the primary way that Se enters the food-web of San Francisco Bay. Using the radioisotope Se-75, we conducted experiments to assess phytoplankton uptake of selenite Se(IV), selenate Se(VI), and organic selenides Se(-II), assessed the variability in Se bioconcentration among algal species, and measured the dependence of cellular Se contents on ambient concentrations of Se. Se(IV) and Se(-II) were more available than Se(VI) to phytoplankton, with uptake of Se(IV) and Se(-II) being strongly correlated (r^2 = 0.9). Addition of Se(IV) reduced algal uptake of Se(-II), suggesting internal control of Se pools by the algae. Accumulation of Se differed among algal species by almost 4 orders of magnitude when exposed to 4.5 nM Se(IV) or Se(-II) and 5 orders of magnitude when exposed to 0.15 nM Se(IV). It is clear that the species composition of phytoplankton communities could have a large impact on Se build-up in food webs. The Se content of the diatom, *Thalassiosira pseudonana*, varied asymptotically with Se(IV) concentration, declining by about 65% as ambient concentrations declined from 1.0 to 0.1 nM. We conclude that organic selenides by phytoplankton can be a significant source of Se to the food-web and that phytoplankton species composition and selenite/selenide concentrations can determine the Se tissue contents of resident herbivores in San Francisco Bay.

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ASSIMILATION OF SELENIUM FROM FOOD BY STRIPED BASS LARVAE

Nicholas S. Baines and N.S. Fisher*

Marine Science Research Center, SUNY Stony Brook, Stony Brook, NY, 11794-5000,
Phone: 631-632-8649, Fax: 631-632-8820, e-mail: nfisher@notes.cc.sunysb.edu

Many commercially and recreationally important fish species spend their larval stages in nearshore or estuarine environments subject to high levels of anthoprogenic contamination. Little is known about the general bioaccumulation of important contaminants by larval fish and virtually nothing is known about the assimilation of ingested contaminants such as Se in larval fish. We assessed the bioaccumulation of Se from food by larval striped bass (*Morone saxatilis*) using the radioisotope Se-75. Brine shrimp (*Artemia franciscana*) nauplii were fed on diatoms (*Thalassiosira pseudonana*) grown in media containing Se-75 selenite. The nauplii were then fed to 40-day old striped bass larvae and the radioactivity in the fish was monitored for two weeks. The assimilation efficiency of Se from the brine shrimp nauplii ranged from 28 to 51% in individual fish. Assimilation of Se from food was significantly greater than observed for Ag, Cd, and Zn. However, the instantaneous first order loss constant for Se approached 10% per day, indicating a half-life of about 7 days for Se in larval fish. This rate of excretion is faster than observed for metals in these fish and faster than Se loss from marine and freshwater bivalves (e.g., *Mytilus edulis* and *Dreissena polymorpha*). The high assimilation efficiency of Se in these fish may partially account for elevated Se concentrations in San Francisco Bay fish which feed on food enriched in this element.

WHICH LOCI PROVIDE GREATEST GENETIC POWER TO DISCRIMINATE SPRING-RUN CHINOOK SALMON OF CALIFORNIA'S CENTRAL VALLEY?

Michael A. Banks*, C. Greig, V.K. Rashbrook, W. Eichert, G. Li, and D. Hedgecock

Bodega Marine Laboratory, P.O. Box 247, Bodega Bay, CA 94923, Phone: 707-875-2077, Fax: 707-875-2089, e-mail: mabanks@ucdavis.edu

Management and protection for endangered runs of California's Central Valley chinook salmon has concentrated attention on the precision of genetic methods used to determine run origin of fish at various stages of their life cycle. Clearly, analysis methods that use data from multiple individuals, such as mixed stock analysis, provide more rigor than individual based methods. However, a number of contexts where run identification for individual samples is important have focused our efforts on maximizing power from genetic information contained at the scale of the individual. For example, determining run origin of individuals salvaged at water diversions enables more rapid and refined management and protection than having to wait until sufficient numbers are sampled for mixed stock analysis. Likewise, identification of individual samples in ocean harvests provides run-specific information about the ocean life stage. This may in turn enable the monitoring of fisheries to avoid over harvesting of threatened or endangered stocks. WHICHLOCI is a computer program designed to determine which of various test loci provide more efficient power for run identification. Results from multiple iterations through a power rank for alternate loci are used to determine which combination of loci would provide confidence levels set by the program user. Statistical parameters such as variance and standard error are attained through evaluation of data sets derived from random re-sampling of the actual population data. We will review the power of microsatellites recently developed for spring-run identification, as well as mitochondrial DNA data (D-loop), as a means of demonstrating this resource.

CULTURE OF DELTA SMELT (*HYPOMESUS TRANSPACIFICUS*) IN SUPPORT OF ENVIRONMENTAL AND RESTORATION STUDIES

Bradd Baskerville-Bridges*, J. Lindberg, J. Van Eenennaam, and S. Doroshov

Animal Science Dept., University of California, Davis, 1 Shields Ave., Davis, CA 95616, Phone: 209-839-0752, e-mail: bridges@tracy.com

Delta smelt (*Hypomesus transpacificus*) were listed as threatened in 1992, launching numerous studies to determine the cause and potential mitigation of the decline. With the CALFED Bay-Delta Program we are developing a reliable and technically feasible method for their culture. The supply of animals from all life stages can benefit researchers working in the areas of: (1) monitoring the health of delta smelt in the wild, (2) contaminant exposure studies, (3) development of taxonomic keys for larvae, (4) improving fish screen design for water diversions in the Delta. Delta smelt have a prolonged larval stage with a high sensitivity to environmental factors, and the production of juveniles has been the major limiting factor. Successful culture from egg to juvenile was achieved at the State Water Project site during the 1998-1999 season. Larger tank size and increased stocking densities have enhanced larval survival and growth. Several experiments were also conducted to test how environmental factors influence the feeding behavior of smelt larvae, including algal cell density, filtered algal water, water turbidity (suspended particles), and light intensity. We established that larvae require suspended particles in the rearing water to initiate feeding. At turbidity levels above 25 NTU the larvae fed well, but there was little or no response in clear water (<5 NTU). The particles appeared to play an important role during feeding, perhaps providing visual contrast in locating their prey (rotifers). High light intensity also enhanced feeding behavior as long as turbidity levels were above 25 NTU. Experiments are also in progress to investigate the effect of temperature (14 °C, 17 °C, and 20 °C) on growth and survival of smelt larvae. Understanding the interactions of larval and juvenile smelt with their environment will improve culture techniques and contribute to mitigation efforts.

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LIFE HISTORY OF THE LONGFIN SMELT (*SPIRINCHUS THALEICHTHYS*) IN THE SACRAMENTO-SAN JOAQUIN ESTUARY, CALIFORNIA

Randall D.Baxter*

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205, Phone: 209-948-7800, Fax: 209-946-6355, e-mail: rbaxter@delta.dfg.ca.gov

The longfin smelt (*Spirinchus thaleichthys*) is a euryhaline, anadromous member of the true smelt family Osmeridae and native to the Sacramento-San Joaquin Estuary. At the end of a prolonged drought (1987-1992), longfin smelt abundance declined to record low levels; it has subsequently recovered, but no longer attains historic levels in response to high outflows. This analysis was undertaken to better understand the life history of longfin smelt and form the basis for future studies. Most longfin smelt spawn between December and March at about age 2. Fecundity varies 10-fold from age 1 to age 3. Pelagic larvae were most abundant in February, coinciding with the historic seasonal outflow peak. More larvae were captured at the surface than at greater depths, facilitating downstream transport by surface currents. Geographic distribution of larvae was strongly associated with outflow: larvae were farther downstream in high outflow than in low outflow years. Growth and distribution of older life stages were also influenced by outflow. Regardless of water year type, longfin smelt used the entire estuary and adjacent ocean during some period in their life.

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BEHAVIORAL RESPONSE TO CLIMATE CHANGE AND THE DECLINE OF STRIPED BASS IN THE SAN FRANCISCO ESTUARY: IMPORTANCE OF ESTUARINE-OCEAN ECOSYSTEM LINKAGES

William A. Bennett[1,2] and E. Howard[3]

[1]**John Muir Institute of the Environment, University of California, 1 Shields Ave., Davis, CA 95616, e-mail: smelt@monitor.net**

[2]**Bodega Marine Laboratory, University of California-Davis, Bodega Bay, CA**

[3]**U.S. Bureau of Reclamation, 2800 Cottage Way, Sacramento, CA 95819**

The effects of climate change can be difficult to distinguish from human interventions acting on fish populations within the San Francisco Estuary. We present analyses suggesting the decline in striped bass is related to a period of frequent El Niños and a concurrent shift in the atmosphere-ocean climate (Pacific Interdecadal Oscillation, PDO) beginning in 1976-1977. Previously, the decline of striped bass has been attributed to impacts on larval and juvenile fish due to exporting fresh water, and recently to density dependence during the pre-adult stage. We show that older striped bass (age 6+ years) migrated more frequently to the warmer Pacific Ocean during multiple El Niño events and the PDO shift, reverting to the behavior of native striped bass populations in Atlantic estuaries. Time series analyses of adult abundance estimates, sport-fishing records, and ocean environmental variables indicate significant associations between a step-like decline in adult abundance in the estuary, and higher occurrence of older adults in the ocean, with a step-like increase in ocean temperatures and relaxation of upwelling. Rises in ocean temperature are also correlated with rates of decline of adult cohorts in the estuary. In addition, reports in the sport-fishing media and by researchers indicate the sudden appearance of substantial numbers of adult striped bass in the Los Angeles area during the recent La Niña in 1997-1998. These results implicate changing ocean conditions as an important factor affecting the residency, and thus apparent mortality of older striped bass in the estuary. Frequent migration from the estuary combined with density dependent survival of pre-adults may be precluding restoration of the estuarine population. This example illustrates the importance of estuarine-ocean linkages and the challenges posed by climate change for management.

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DENSITY DEPENDENCE, BEHAVIOR, AND ENVIRONMENTAL INFLUENCES ON DELTA SMELT: IMPLICATIONS FOR RESTORATION

William A. Bennett*[1,2,3], B. Herbold[4], J.A. Hobbs[2,3], and D.P. Martasian[2]

[1]**John Muir Institute of the Environment, University of California, 1 Shields Ave., Davis, CA 95616, e-mail: smelt @monitor.net**

[2]**Bodega Marine Laboratory, University of California at Davis, Bodega Bay, CA 94923**

[3]**Department of Wildlife, Fish, and Conservation Biology, University of California, 1 Shields Ave., Davis, CA 95616**

[4]**U.S. Environmental Protection Agency, 75 Hawthorne Street, San Francisco, CA 94105**

Restoration of the delta smelt, *Hypomesus transpacificus*, population in the San Francisco Estuary is frustrated by limited understanding of the interaction of human interventions with the basic population ecology of this threatened species. We present analyses of UC Davis culturing and aging studies that suggest delta smelt use bi-weekly tidal cues for spawning and hatching. In addition, analyses of Interagency Ecological Program monitoring data implicate density dependence, the abundance of 2 year-old spawning individuals, and various external factors (e.g. exotic predators and freshwater exports) contribute to regulate the dynamics of the population. Numbers of eggs spawned in culturing facilities during 1998-1999 are associated with bi-weekly spring tides and potential hatch dates are associated with neap tides, as characterized by the root-mean-square of tidally-filtered water level. Back-calculation of hatch dates from 120 otoliths indicate hatching during or near neap tides. These results suggest that spawning during spring tides may reduce egg stranding, and hatching during neap tides increases the probability that larvae can remain near spawning locations. Delta smelt juvenile and adult abundance indices exhibit significant auto-correlation when lagged by 2 years, indicating the potential importance of a 2-year life cycle. Stock-recruit modeling indicates density dependence between the juvenile and adult stages, as well as the potential importance of a 2-year life cycle. Correlations among residuals from stock-recruit models and external factors indicate exotic inland silversides and exports may influence the larval to juvenile stages, whereas exports may have a greater influence on population dynamics by affecting pre-spawning adults during the winter. These findings suggest the sharp decline in 1980-1981 was caused by excessive losses to water diversion operations followed by severe flooding in 1983. Gradual improvement in residual abundance since that time implicates density dependence as an important barrier for restoration. Taken together, these results provide new directions for research and management.

OBSERVATIONS REGARDING NATURAL ORGANIC MATERIAL AND ITS EFFECT ON DRINKING-WATER QUALITY IN THE SACRAMENTO-SAN JOAQUIN DELTA

Brian A. Bergamaschi, M.S. Fram, and R. Fujii

U.S. Geological Survey, Placer Hall, 6000 J Street, Sacramento, CA 95819,
Phone: 916-278-3053, Fax: 916-278-3071, e-mail: bbergama@usgs.gov

Twenty-two million people drink water originating from the tidal reaches of the Sacramento-San Joaquin River Delta, California, USA, a region largely composed of below-sea-level, peat-rich islands that are maintained for agricultural production by a network of levees and pumps. These waters contain natural organic materials (NOM) that react to form disinfection byproducts (DBPs) when treated with chlorine for use as drinking water. DBPs present a potential health hazard, and therefore the concentrations of some DBPs are regulated in finished drinking water. High NOM concentrations in Delta waters combined with high bromide levels from tidal mixing of brackish waters frequently result in source waters that, upon chlorination, potentially form DBPs in excess of regulated levels.

Considerable debate exists concerning the source of the reactive NOM that forms DBPs in chlorine-treated waters: for example, are they derived from soil humic materials, degrading agricultural crops, or algae? Several studies are investigating the relationship between geochemical and biological processes in the Delta, composition of the NOM, and the molar capacity of NOM to form DBPs by examining the geographic and chemical variability in NOM content, composition, and quality. Coordinated research in the watershed using molecular-level carbon-isotope ratios and compositional characterization of NOM with kinetic chlorination experiments is challenging existing paradigms regarding origins of DBP precursors and providing new insights into the most reactive forms of NOM. The results of these studies suggest possible strategies for mitigating DBP precursors in the watershed. These results also add to our fundamental understanding of the fate and transport of organic material in watersheds.

TRAVEL TIME AND CONDITION OF JUVENILE CHINOOK SALMON PASSED THROUGH RED BLUFF RESEARCH PUMPING PLANT

Sandra M. Borthwick[*1] **and E.D. Weber**[2]

[1]**Bureau of Reclamation, P.O. Box 159, Red Bluff, CA 96080, Phone: 530-528-0512, Fax: 530-528-0612, e-mail: sborthwick@mp.usbr.gov**

[2]**256 W. Prospect Road #68, Fort Collins, CO 80526**

Pumps, screens, and bypasses installed at Red Bluff Research Pumping Plant (RBRPP) in combination represent new fish passage technologies. Travel time, mortality, injury and descaling of juvenile chinook salmon passed through RBRPP was evaluated. The helical pump and two Archimedes lifts each have their own bypass including vertical wedge-wire screens, above and below ground bypasses, and an outfall into the Sacramento River. One-quarter of the chinook salmon released into pump intakes remained within RBRPP 48 h after release. Fish passage rates were significantly lower for sunrise versus sunset trials. Delays occurred in the screening facility and in the 152-cm diameter underground bypass. Pulsing flows were ineffective at moving fish through the screening facility, but were effective at moving fish through the 152-cm bypass. There were no significant differences in the condition of salmon that exited the bypass on their own volition versus those that were flushed.

In 16 trials where salmon were released and later recaptured at the river outfall, mortality of fish passed through pumps and bypasses (treatment group) ranged from 3% to 4% at 96 h; mortality of fish passed through bypasses only (control group) ranged from 1% to 3%. Mean percent body-surface descaled and mean percent of salmon with non-lethal injuries was <1.2 and <8.0, respectively for both pump types and did not differ significantly between treatment and control groups. There were no significant differences in condition of salmon passed through the helical pump versus the Archimedes lifts. There also were no differences between pump bypasses. Low mortalities, descaling, and injuries to salmon passed through RBRPP occur mainly as fish travel through the pumps, screening facility, and plunge pool. Few adverse effects are associated with the underground bypass. Findings from this study should be considered when developing future CALFED projects.

SEDIMENT BED FLUX MEASUREMENTS IN SUISUN CUTOFF

Matthew L. Brennan*[1], D.H. Schoellhamer[2], J.R. Burau[2], and S.G. Monismith[1]

[1]**Environmental Fluid Mechanics Lab, Dept. Civil and Enviro. Eng., Stanford University, Stanford, CA 94305-4020, Phone: 650-725-5948, Fax: 650-725-9720, e-mail: mbrennan@stanford.edu**

[2]**U.S. Geological Survey, Placer Hall, 6000 J St., Sacramento, CA 95819**

We measured near-bed water velocity, suspended-sediment concentration, and turbulent sediment flux in a partially stratified estuary during a range of neap and spring tides. The field site was located in Suisun Cutoff, a 500-m-wide by 2000-m-long channel in the northern reach of San Francisco Bay, 65 km landward of the estuary's mouth. Data were collected continuously for 8 days in October 1999 from the end of a neap tide through the strongest portion of a spring tide. Because the study occurred during low freshwater discharge, conditions at the site were partially stratified with the strongest stratification occurring on neap ebbs. Acoustic probes positioned at 49 cm and 97 cm above the bed simultaneously measured velocity (proportional to the Doppler shift) and suspended sediment concentration (proportional to the backscatter intensity). From these velocity and concentration measurements, we calculated the turbulent sediment flux. The sediment flux measurements indicate that bed sediments eroded more easily during the first 2 hours of flood tides than at any other portion of the tide. This time-dependent erodibility may be caused by bed strengthening during the longer slack-before-ebb and/or salinity-enhanced sediment shear strength. The turbulent sediment flux was also inversely related to the gradient Richardson number. This indicates that stratification damps the capacity of turbulent eddies to erode sediment, especially on the more stratified ebb tides. In addition to these asymmetries in sediment response, tidal currents at the site were asymmetrically flood-dominated, especially during neap stratification. These asymmetries in tidal currents, erodibility, and bed shear combined to create a mean (8-day averaging interval) landward flux of sediment of 14 g/s/m^2 for this experiment.

BIOLOGICAL AND HYDRAULIC PERFORMANCE OF TWO UNCONVENTIONAL, HIGH SWEEPING VELOCITY, SELF-CLEANING FISH SCREEN TECHNOLOGIES

James W. Buell*

Buell and Associates, Inc., 2708 S.W. Bucharest Ct., Portland, OR 97225, Phone: 503-203-1248, Fax: 503-203-8288, e-mail: buell@interserv.com

Two "unconventional" fish screen technologies, each incorporating very high sweeping velocities, were tested for biological performance, both with excellent results. Hydraulic characteristics were also investigated. Both technologies have been found to operate successfully in full scale installations without the need for mechanical or other cleaning devices, by taking advantage of inherent hydraulic characteristics to prevent debris accumulation.

1. East Fork [Hood River] Irrigation District (EFID) incorporated a prototype overflow weir "Coanda" screen into their diversion withdrawing up to 127 cfs, near Parkdale, OR. This design results in very high sweeping velocities and excellent self-cleaning characteristics, but calculated approach velocities greatly exceed generally accepted fish protection criteria. Biological performance tests were conducted using newly emergent chinook salmon and steelhead fry and steelhead smolts.

2. Farmers' Irrigation District (Hood River, OR) constructed a full-scale (75 cfs) high sweeping velocity horizontal flat plate screen in their irrigation ditch as a prototype for a planned permanent installation. Unlike the Coanda technology, approach velocities for this screen are very low (0.1 to 0.2 fps). Newly emergent steelhead fry, chinook salmon fingerlings and steelhead smolts were used to test biological performance.

No injuries, behavioral anomalies or latent mortalities resulted from exposure to either screen technology for any of the three species/life stages tested. Both the "Coanda" and the high velocity flat plate fish screen technologies performed at least as well as any other screening systems reported and better than most. Each of these technologies may have application at sites where complicated cleaning systems present problems.

RELATIVE ABUNDANCE OF JUVENILE CHINOOK SALMON IN THE LOWER SACRAMENTO RIVER, SAN JOAQUIN RIVER, AND DELTA

R.H. Burmester and Patricia L. Brandes*

U.S. Fish and Wildlife Service, 4001 N. Wilson Way, Stockton, CA 95205,
Phone: 209-946-6400 ext. 308, Fax: 209-946-6355, e-mail: pbrandes@delta.dfg.ca.gov

In the late 1970s, the precursor of the Interagency Ecological Program for Sacramento-San Joaquin Estuary Began, generally springtime, monitoring of fall run chinook in the lower Sacramento River and Delta. With the listing of winter run chinook salmon, and declines in the late-fall and spring run chinook populations, sampling was expanded and evolved to include more locations and was conducted on a more year-round basis to detect the relative abundance and timing of all the races of juvenile salmon in the lower rivers and Delta. Beach seining in the lower Sacramento River and North Delta, and midwater trawling at two locations (Sacramento and Mossdale) were used to detect the entry of juvenile salmon into the Delta. Beach seining was also used to index the abundance and distribution of juvenile salmon in the Central and South Delta. The midwater trawling at Chipps Island was used to detect the emigration of juveniles from the Delta. Monthly and daily catch per cubic meter for each race of juvenile salmon (late-fall, winter, and fall/spring), and juvenile salmon between 70 and 150 mm detected between October 1 and December 31 (presumably spring run yearlings) was plotted for each year. The month when peak abundance occurred for each of the races varied between years. Monthly occurrence was also standardized by year, and averaged for all years. Peak occurrence of late-fall, winter, fall/spring run in the Delta (in the beach seine) was in December, December, and March, respectively. Peak occurrence of late-fall, winter, fall/spring run was in November, March, and April in the Sacramento Kodiak trawl, and in December, March, and May for the Chipps Island midwater trawl, respectively. Peak occurrence of fall run in the lower San Joaquin River beach seine and Mossdale Kodiak trawl was in February and May, respectively.

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REVIEW OF FACTORS AFFECTING FISH SALVAGE AT SOUTH DELTA PUMPING PLANTS

Thomas C. Cannon*

Foster Wheeler Environmental Corporation, 3947 Lennane Drive, Sacramento, CA 95834, Phone: 916-928-4804, Fax: 916-928-0594, e-mail: tcannon@fwenc.com

Entrainment or salvage of fish at the CVP and SWP Delta pumping plants has been identified by CALFED as one of twelve issues dealing with uncertainties that relate to the choice of a through-Delta alternative. CALFED's Delta Entrainment Fish Team (DEFT) and the Water Management Development Team have over the last two years been evaluating means for operating the SWP and CVP projects to minimize entrainment and salvage of fish. Analysis of available salvage data in combination with Delta hydrology and fish survey data has provided insights into operational schemes that will reduce salvage-entrainment effects on Delta fish populations. An analysis of salvage and hydrology data from 1980-1997 indicates the magnitude of salvage of important fish species is related to export rate, outflow, net flows in the lower San Joaquin River, and adult population size and young production and distribution in the Bay-Delta system. Many of the specific salvage events in the past two decades can be explained by these factors. The combination of seasonally decreasing outflow and increasing or high exports explains many of the major salvage events. Very high exports (10,000 to 14,000 cfs) in winter has also lead to high salvage. Mortality related to salvage-entrainment may be contributing to population declines. Some of the specific salvage events that occurred historically, particularly those related to high spring and early summer exports would today be limited in extent because of the 1995 water quality standards, biological opinions, AFRP actions, and other actions such as the VAMP export restrictions on spring exports. Proposed new CALFED programs such as the Environmental Restoration Program (ERP) and the Environmental Water Account (EWA), along with new CVPIA actions (e.g., b2, b3) could further reduce the salvage-entrainment risks in the Central Valley and potentially contribute to recovery of fish populations.

ORGANIC MATTER SOURCES IN THE SACRAMENTO-SAN JOAQUIN RIVER DELTA AS INFERRED THROUGH THE USE OF BIOMARKERS

Elizabeth A. Canuel*, V. Pilon, and M. Ederington-Hagy

Virginia Institute of Marine Science, P.O. Box 1346, Gloucester Point, VA, 23062
Phone: 804-684-7134, Fax: 804-684-7786, e-mail: ecanuel@vims.edu

The Sacramento River-San Joaquin River Delta is characterized by a diversity of habitats and associated primary producers. At present, we do not have a clear understanding of how production at higher trophic levels is supported within the diverse ecosystems that encompass the Delta. As part of this CALFED-supported study, we are utilizing geochemical indicators (lipid biomarkers and stable isotopes) to identify the sources of particulate organic matter (POM) in sub-environments characteristic of the Delta, with the goal of identifying habitats most likely to support production at higher trophic levels. Preliminary results indicate that sources of POM vary both within and among these habitats and sources of carbon derived from various primary producers differ in their potential usefulness to heterotrophic organisms. We find higher levels of polyunsaturated fatty acids (PUFA; indicators of labile phytoplankton-derived carbon) and sterols indicative of algal sources on the San Joaquin vs. Sacramento Rivers. While PUFA comprised 32% to 47% of the fatty acids at Mossdale, they made-up only 20% to 31% of the fatty acids at Rio Vista. Sterol distributions corroborate the greater abundance of algal carbon at Mossdale. Temporal variations in organic matter quality are also evident. Lipid biomarker compounds indicative of algal sources were generally enriched at the river sites during May (Rio Vista) and July (Mossdale) while there was little temporal variability at our baseline tule marsh site in Cutoff Slough. Stable carbon and nitrogen isotopic signatures vary in response to fluctuations in productivity and river flow. Carbon isotopic signatures were most enriched in May through October 1999 but were depleted in January 1999. Nitrogen isotopes were depleted in May through October and enriched in January. In considering rehabilitation strategies managers should consider both the amount of carbon produced within particular habitats as well as its composition as both may influence OM availability to heterotrophic organisms.

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THE HYDROCLIMATOLOGY OF CALIFORNIA FLOODS AND DROUGHTS

Daniel Cayan[1] **and M. Roos**[2]

[1]**Scripps Institution of Oceanography, University of California-San Diego, La Jolla, CA 92037**
Phone: 619-534-4507, e-mail: drcayan@usgs.gov

[2]**Retired, Chief Hydrologist, California Department of Water Resources, Sacramento, CA**

Extreme events ("disturbances") are by definition rare, but can leave their marks on ecosystems for many years. Recent analyses, e.g., on the American River suggest that large floods and extreme precipitation events have been much more common in parts of the Sacramento-San Joaquin drainage during the second half of the 20th century than during the first half. Such differences have called assumptions of statistical stationarity that usually underlie most flood- and drought-frequency analyses into question. Potential influences on California's floods by human-induced changes in atmospheric greenhouse gases and in land-cover and use in the region's basins may be changing the climatic conditions in the areas under CALFED's influence. In addition, however, floods (and droughts) in the San Joaquin and Sacramento Basins are related to El Niño, La Niña, and other natural Pacific-climate fluctuations. Linkages of floods to these hemispheric and global climate processes, in some cases, are straightforward and, in others, more convoluted. The present understanding of these largest scale influences on California's floods and droughts will be reviewed and used to characterize the interannual extremes of climate variability as will affect CALFED operations.

PERFORMANCE AND BEHAVIOR OF JUVENILE CHINOOK SALMON NEAR A SIMULATED FISH SCREEN

Joseph J. Cech Jr.[*1], C. Swanson[1], P.S. Young[1], T. Chen[1], M. Kondratieff[1], and T. MacColl[2]

[1]**Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, CA 95616 Phone: 530-752-3103, Fax: 530-752-4154, e-mail: jjcech@ucdavis.edu**

[2]**California Department of Water Resources, 3251 S Street, Sacramento, CA 95816**

In the Sacramento-San Joaquin watershed, chinook salmon (*Oncorhynchus tshawytscha*) parr and smolts are exposed to water diversions along their migratory path. Loss of these young fish at diversions, by entrainment and/or fish screen-related injuries and mortality, is thought to have contributed to the species' population decline. To develop fish screen flow and design criteria that better protect this species, we examined performance and behavior of juvenile fall-run chinook salmon in complex flow regimes similar to those near screened water diversions in the Fish Treadmill, a large annular flume equipped with a fish screen. Fish were tested for 2 h in ten flow regimes derived from combinations of an approach flow (through the screen, range: 0 to 15 cm/s) and sweeping flow (past the screen, range: 0 to 62 cm/s), two seasonal temperatures (12 and 19 °C), and during the day (light conditions) and night (dark conditions). We measured screen contact frequency (contacts/fish*min), swimming velocity (cm/s through the water), rheotaxis (orientation relative to resultant flow), velocity past the screen (cm/s over the ground), and post-experiment survival and injury. Both parr and smolts experienced frequent flow-dependent temporary screen contacts (especially at night) but few fish became impinged on the screen. Survival was uniformly high but, for parr, injury rates were directly related to screen contact rates. Parr exhibited greater positive rheotaxis than smolts at intermediate flows, slowing their downstream screen passage. Based on these results, optimal fish screen design for young chinook salmon should minimize screen contact and promote downstream passage. Research supported by DWR, CDFG, USBR, and CALFED.

CALFED SALMON RESTORATION PROJECTS: ARE WE ACHIEVING THE ECOSYSTEM RESTORATION PLAN STRATEGIC GOALS AND OBJECTIVES?

Edward F. Cheslak* and W.J. Shaul

Jones & Stokes Associates, 2600 V Street, Sacramento, CA 95818
Phone: 916-737-3000, Fax: 916-737-3030, e-mail: edc@jsanet.com

A major goal and objective of the CALFED Ecosystem Restoration Program (ERP) is to achieve recovery of self-sustaining populations of the four runs of chinook salmon that rely upon the Bay-Delta estuary and its watershed. Numerous projects have been funded by CALFED since its inception in 1995. However, no comprehensive evaluation of the number of projects, their geographic distribution, scope, effectiveness, or relevance to achieving ERP strategic goals has been reported. We present the results of such an evaluation as a tool for determining the overall progress of the ERP in attaining one of its principal strategic objectives. The total number of projects (weighted by cost and sorted by targeted run) is examined; the geographic distribution of projects is shown and evaluated in relationship to the distribution of at-risk populations; the scope of each project has been reviewed, categorized (by key words), and evaluated with respect to its effectiveness; and the contribution of the projects to achieving the ERP strategic goals is ranked and reported. The results provide insight into what salmon restoration activities are occurring, where they are occurring, and what future actions might be warranted. In addition, it is recognized that ERP actions must be undertaken in the face of large uncertainties about the response of the system to these actions. Consequently, these actions are being taken as experiments in an adaptive management framework. The question arises: What are we learning from these experiments and how are we adapting the management actions? We address this question by utilizing a conceptual model for chinook salmon presented in the ERP Strategic Plan and evaluating how the various projects contribute to refinement of this model. In this way, we attempt to determine what is being learned about the operation of this complex system and where critical voids in our understanding remain.

BASIC SCIENCE IN SUPPORT OF ECOSYSTEM RESTORATION: LESSONS FROM A RESEARCH PROGRAM SUPPORTED BY CALFED CATEGORY III

James E. Cloern*

U.S. Geological Survey, MS496, 345 Middlefield Rd., Menlo Park, CA 94025
Phone: 650-329-4594, Fax: 650-329-4327, e-mail: jecloern@usgs.gov

As a result of the sustained monitoring by IEP, we know with certainty that some biological populations in the Sacramento-San Joaquin Delta are smaller now than they were only three decades ago. For example, Jim Orsi and colleagues at CDFG have documented remarkable declines in the abundances of freshwater zooplankton (cladocerans, rotifers, native copepods). We know surprisingly little about the causes of these population declines and the degree to which they are linked to impairment of ecosystem functions necessary to support fish production. In response to gaps in our knowledge about the food resource that supports biological production at the foodweb base, we designed a program of basic research that has been supported by CALFED Category III for two years. Progress reports given in the following six papers will answer basic questions about the origin, quantity, quality, availability and utilization of organic matter as a food resource for the primary-consumer biota (e.g. zooplankton). Each progress report concludes with results of basic science, translated into practical lessons that can guide development of an ecosystem restoration plan for the Sacramento-San Joaquin Delta. Lessons from this overall project include the following: (1) critical gaps in knowledge exist about key ecosystem functions and processes in the Delta, including those required to sustain specific populations; (2) the success of attempts at ecosystem restoration/rehabilitation is therefore critically dependent upon new programs of ecosystem research designed to close those knowledge gaps; (3) all of the remaining science questions are complex and best attacked through team approaches that (a) integrate the physical sciences with geochemistry and biology-ecology, and (b) attack complex problems through a diversity of integrated approaches including laboratory experimentation, field experimentation, restrospective and synthetic analyses of historic data, and modeling. The following six papers exemplify this style of integrated research and its application to guide ecosystem restoration.

BIODIVERSITY IN SOIL SEED BANKS OF RESTORED AND NATURAL SALT MARSHES OF CALIFORNIA

Gretchen C. Coffman[*1], S.S. Anderson[2], and R.F. Ambrose[3]

[1]**University of California, Department of Environmental Health Sciences, Charles E. Young Drive South, 46-059 CHS, Box 951772, Los Angeles, CA 90095-1772 and Romberg Tiburon Center for Environmental Sciences, 3150 Paradise Drive, PO Box 855, Tiburon, CA 94920, Phone: 415-771-7791, Fax: 310-206-3358, e-mail: gcoffman@ucla.edu**

[2]**Department of Organismic Biology, Ecology and Evolution, University of California, Los Angeles, 621 Charles E. Young Drive South, Box 951606, Los Angeles, CA 9009-1606**

[3]**Environmental Science and Engineering Program, University of California, Los Angeles, EHS, 46-059 CHS, Box 951772, Los Angeles, CA 90095-1772**

Salt marsh communities are highly productive ecosystems that line coastal lagoons and estuaries throughout California. In the last 20 years, resource managers and scientists have attempted to restore numerous salt marsh systems in California altered by human development, farming and salt production. Restoration success has traditionally been measured by estimating floristic cover and diversity of adult plants. However, species diversity and density of soil seed banks may represent a more accurate indication of future salt marsh restoration performance. The objective of our study was to investigate soil seed banks within and among natural and restored salt marshes of coastal California. From 1996-2000, seed banks in ten salt marshes (1 to 100 years old) were sampled throughout California, including several locations in the San Francisco Bay. Samples were collected from two tidal levels and four distances along a main tidal channel. Greenhouse and field germination experiments were conducted to estimate seed bank biodiversity. Results showed highest species diversities (Shannon-Wiener Index) at the wrack line, from 0.17 at Cargill Marsh (1 year) in Northern California to 1.96 at Malibu Marsh (16 years) in southern California. Lower tidal elevations resulted in lower species diversity. Seed diversity and density increased with distance from mouth of tidal channels. Species diversity was significantly higher in marshes of Southern versus Northern California ($f = 14.124$, $df = 7$, $P < 0.0005$; $f = 25.167$, $df = 7$, $P < 0.0005$). *Salicornia virginica* (common pickleweed) dominated seed banks at all sites, with highest densities at the wrack line. Northern California marshes had significantly higher *S. virginica* soil seed bank densities (wrack line, $f = 13.106$; $P < 0.001$). Trends in *S. virginica* seed densities among marshes of various ages appear low in newly restored marshes, peak in older restored marshes, and level off again in natural marshes. We suggest using this general trajectory as a performance curve for salt marsh restoration planning/monitoring throughout California.

ANTHROPOGENIC INFUENCES ON RATES OF GEOMORPHIC AND FLUVIAL PROCESSES IN WILDCAT WATERSHED: IMPLICATIONS FOR RESTORATION

Laurel M. Collins*

San Francisco Estuary Institute, 180 Richmond Field Station, 1325 S. 46th St., Richmond, CA 94804, Phone: 510-231-9416, Fax: 510-231-9414, e-mail: laurel@sfei.org

A watershed assessment was performed to determine historical changes in the supply and distribution of water and sediment in Wildcat Creek, located on the east side of the Berkeley Hills, Contra Costa County. With an 8.7 sq mi drainage area, Wildcat Creek mainstem channel flows 7.5 miles along its earthflow-dominated canyon that is managed primarily as open space, 3.6 miles along its highly urbanized alluvial plain of San Pablo and Richmond, and 0.7 miles along its tidal slough that has had over 50% reduction in its tidal marsh. The drainage density of 9.2 miles of channel per square mile is about 34% greater than its historical condition. Wildcat Creek has 265 culverts, 21 bridges or box culverts, 1 mile of trapezoidal-shaped flood control channel with a constructed sediment catchment basin, two man-made reservoirs in its canyon, 11% impervious area, 11.4 miles per square mile of dirt road and trail density in the canyon, and about 1/3 of the watershed has been continuously grazed for 182 years. The effects of these impacts will be reported relative to rates of different erosional processes and to anthropogenic influences. The recruitment of woody debris, distribution of pools and sediment size classes will be presented. Potential for restoration in the context of reducing both accelerated rates of erosion and increased runoff will be discussed in the context of the entire watershed.

REGULATORY IMPACTS OF MERCURY IN CALIFORNIA WATERWAYS

Janis B. Cooke*

Central Valley Regional Water Quality Control Board, 3443 Routier Road, Sacramento, CA 95827, Phone: 916-255-3372, Fax: 916-255-3015, e-mail: cookej@rb5s.swrcb.ca.gov

Mercury in California waterways poses a significant health concern for humans and wildlife. Mercury is a potent neurotoxin that can also affect immune and reproductive systems. The primary source of intake, excepting occupational exposure, is consumption of contaminated fish. There are eleven waterbodies in the Central Valley, plus the Delta and San Francisco Bay, for which mercury issues will be addressed through Total Maximum Daily Loads (TMDL). In the TMDL process, Regional Water Quality Control Board staff will identify numeric water quality targets designed to restore the beneficial uses of impaired waters if the targets are met. Mercury in fish tissue is being proposed as the primary target, in part because tissue measurements will most closely indicate when the risk of mercury toxicity has been reduced. Key components needed for a fish target are the acceptable daily intake of mercury and fish consumption rate. Lacking localized consumption studies, information from national and regional surveys will be used. Comparisons between fish tissue targets for humans and wildlife and other targets will be presented.

COOPERATIVE PARTICIPATION IN DELTA HABITAT DEVELOPMENT AND LEVEE MAINTENANCE

Gilbert Cosio*

MBK Engineers, 2450 Alhambra Blvd., 2nd Floor, Sacramento, CA 95817
Phone: 916-456-4400, Fax: 916-456-0253, e-mail: mbkgib@aol.com

Levee maintenance and ecosystem restoration, two terms that are rarely uttered in the same breath in the Delta, must some how work together for CALFED to succeed. DWR and DFG's AB360 Delta Levees Program have implemented several projects that will act as the prototype for the future CALFED levee program and its ERPP. The key is matching available opportunities with the spirit of cooperation and the understanding that the end justifies the means. Canal Ranch Tract in the North Delta Region had a levee in need of erosion repair. The levee location made it ideal to try a project that repaired the eroded area and created diverse fish and wildlife habitat instead of creating a sterile rip rapped bank. Decker Island on the lower Sacramento River is a barren dredge disposal area and Webb Tract was suffering from unstable levees. By matching the two of them up, 15 acres of new diverse tidal wetland and riparian habitat will be created, and a levee that nearly failed in 1998 will be stabilized. Grand Island has a portion of its rip rapped levee with a large cross section without any vegetation along Steamboat Slough. Implementation of an existing demonstration project under the Lower Sacramento River Revegetation Project will provide valuable data on how vegetation can be introduced on to levees without compromising their integrity. These projects and future projects rely heavily on trust between reclamation districts and regulatory agencies. The goal is a win-win for levees and the environment. However, achieving this goal means giving a little and departing from the old prejudicial thinking that has kept these two schools of thought in direct opposition. We will discuss how to find these opportunities, what we have learned, and what to stay away from in accomplishing the overall CALFED objective to "get better together."

NATIVE AND ALIEN FISH ASSEMBLAGES IN RELATION TO ENVIRONMENTAL VARIATION IN THE COSUMNES RIVER FLOODPLAIN

Patrick K. Crain*, P.K., P. B. Moyle, and K. Whitener

Wildlife, Fish, and Conservation Biology, University of California, Davis, 1 Shields Ave., Davis, CA 95616, Phone: 530-752-0205, e-mail: pkcrain@ucdavis.edu

Fish on the Cosumnes River floodplain were sampled from February to May 2000 with point abundance electrofishing. Using canonical correspondence analysis we examined relationships among fish species and 17 environmental variables. The species group into two assemblage, one made up mainly of native fishes and one made up mainly of alien fishes. The two fish assemblages differed in their association with current velocity, water depth and terrestrial vegetation. The native fish assemblage had its highest abundance in shallow, flowing areas associated with flooded annual vegetation, while the alien species assemblage was found in association with deeper, quiet water without a strong association with flooded vegetation. The results suggest that native fishes are adapted for use of the active floodplain, while alien fishes use habitats similar to those of non-flooded areas.

FISH ASSEMBLAGES AND ENVIRONMENTAL GRADIENTS IN THE COSUMNES RIVER BASIN

Patrick K. Crain*, P.B. Moyle, and K. Whitener

Wildlife, Fish, and Conservation Biology, University of California, Davis, 1 Shields Ave., Davis, CA 95616, Phone: 530-752-0205, e-mail: pkcrain@ucdavis.edu

The Cosumnes River is the largest stream in the Sierra Nevadas that has a natural flow regime and a functional floodplain. Fish were sampled throughout the basin to examine interactions between upper and lower watershed in an undammed stream. Canonical correspondence analysis was used to examine basin wide trends in fish assemblages. Elevation, stream gradient, water temperature, and turbidity were significant environmental descriptors related to different fish assemblages. Native fish dominated assemblages of the upper and upper middle portions of the basin. The lower middle reaches contained a mixture of alien and native fishes, while the lower portions were dominated by alien species. The results suggest that biotic and abiotic influences in the lower basin give alien species an advantage over native species and that the lower basin acts as a "sink" for juvenile native fish produced in the upper basin.

SELENIUM IN THE SAN FRANCISCO BAY AND DELTA: HISTORICAL TRENDS AND PRESENT STATUS

Gregory A. Cutter*, L.S. Cutter, M. Doblin, and S. Meseck

Department of Ocean, Earth, and Atmospheric Sciences, Old Dominion University, Norfolk, VA 23529-0276, Phone: 757-683-4929, Fax: 757-683-5303, e-mail: gcutter@odu.edu

Selenium exists in multiple oxidation states and its bioavailability depends on this chemical speciation. Thirteen years ago our first measurements of dissolved Se in the San Francisco Bay established that selenite (SeIV) showed mid-estuarine input, while selenate (SeVI) and organic selenide (Se-II) show both input and removal, depending on river flow rate (residence time). Furthermore, selenite was introduced by effluents from oil refineries, while organic selenide and selenate were largely delivered by the Sacramento River (SR). However, high concentrations of selenate (50x SR) and organic selenide (30x SR) were found in the San Joaquin River, entering the Bay via the Delta. Because of concerns over the effects of Se on foodweb restoration, we have been re-examining the Se cycle in the Delta and Bay with funding from CALFED. While the concentrations of total dissolved Se in the Bay are nearly unchanged over 13 years, the abundance of selenite has decreased (from 45% to 25% of the total), perhaps from changes in oil refinery effluents. Se in suspended particles (seston) is <15% of the dissolved inventories and ranges from 0.1 to 1.7 µg/g, relatively unenriched compared to phytoplankton (1 to 4 µg/g), and zooplankton (0.5 to 6.6 µg/g). San Francisco Bay seston is comprised not only of Se-rich phytoplankton, but also inorganic particles which effectively "dilute" total particulate Se. Nevertheless, >75% of Se in seston is bioavailable organic selenide. Concentrations of total sedimentary Se at different sites range from 0.2 µg/g to 1.1 µg/g, with highest concentrations in the Delta; elemental Se (up to 80%) and organic selenide (up to 60%) are the major chemical forms. The Se:C ratios in sediments are similar to those in phytoplankton and seston (2.0 to 6.0 x 10^{-6}), but the predominance of elemental Se likely makes sedimentary Se less bioavailable to benthic organisms than that in seston.

PERSISTENT CONTAMINANTS OF HUMAN HEALTH CONCERN IN SPORTFISH FROM THE DELTA AND SACRAMENTO RIVER

Jay A. Davis*[1], M.D. May[1], G. Ichikawa[2], and D. Crane[3]

[1]**San Francisco Estuary Institute, 1325 South 46th St., Richmond, CA 94804, Phone: 510-231-9539, Fax: 510-231-9414, e-mail: jay@sfei.org**

[2]**Moss Landing Marine Laboratory, Moss Landing, CA**

[3]**Water Pollution Control Laboratory, California Department of Fish and Game, Rancho Cordova, CA**

Little information is available on sportfish contamination in the Delta. In 1997 and 1998, studies of chemical contamination in largemouth bass and white catfish were conducted in the Delta, the Sacramento River, and the San Joaquin River to address the need for more information in these waterbodies. Mercury concentrations were frequently above the screening value. Nearly two thirds of the largemouth bass and white catfish samples analyzed in 1997 and 1998 exceeded the mercury screening value (17 of 26 largemouth bass and 11 of 18 white catfish). Consistent regional variation has been observed in both species, with the highest concentrations in the lower Sacramento River watershed, moderately high concentrations in the lower San Joaquin River watershed, and generally low concentrations in the central and southern Delta. Concentrations of PCBs were above the screening value in 29% of the samples (8 of 15 white catfish and 4 of 26 largemouth). Available data suggest that PCBs are elevated in localized hotspots rather than on a regional basis. Concentrations of DDT exceeded the screening value in 17% of the samples (6 of 15 white catfish and 1 of 26 largemouth bass). All of the samples above the DDT screening value were obtained from the south Delta or lower San Joaquin River watershed. Other chemicals which are possible concerns in the Delta include dieldrin, toxaphene, arsenic, PAHs, and dioxins. The following recommendations are based on these findings: (1) long-term monitoring should be conducted to track trends in contaminants of concern relative to screening values; (2) further fish sampling should be conducted in the San Joaquin River watershed to characterize human health concerns related to chemical contamination; and (3) a fish consumption study should be conducted in the Delta and Central Valley.

SPATIAL AND TEMPORAL DISTRIBUTION OF TWO COPEPODS IN RELATION TO DELTA SMELT

Michael Dege*

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: mdege@delta.dfg.ca.gov

In 1995 the 20-mm Survey was initiated to monitor the spatial and temporal distribution of juvenile delta smelt throughout the Delta and Estuary. Although, the primary objective was to monitor juvenile delta smelt, a secondary objective was to identify zooplankton associated with delta smelt. Zooplankton was sampled concurrently with the 20-mm survey using a Clark-Bumpus net attached to the trawl frame. The native, *Eurytemora affinis* and introduced *Pseudodiaptomus forbesi* copepods have been identified as a major food component of delta smelt. Since its introduction, *P. forbesi* have displaced *E. affinis* both in the environment and diet of juvenile and adult delta smelt. Although, this displacement is generally restricted to the warmer times of the year, *E. affinis* can be prevalent in the winter months. A previous diet study indicated a delayed selectivity shift during the transition from one dominant copepod to the next. Such results suggest this may be due to a combination of density, coexistence and feeding behavior, among other factors. Although the diet of delta smelt has been identified as a possible factor for its decline, it's not known whether this transition from one species to another has any detrimental effects to the development of juvenile delta smelt. Aspects affecting the diet, including the distribution and density of preferred prey items, could help answer questions that assist in the recovery of delta smelt, and in turn, improve management options.

SIERRA NEVADA RUNOFF INTO SAN FRANCISCO BAY—WHY HAS IT COME EARLIER RECENTLY?

Michael Dettinger

U.S. Geological Survey, 5375, Kearny Villa Road, San Diego, CA 92123
Phone: 858-534-4507, e-mail: mddettinger@usgs.gov

Since the late 1940s, snowmelt and runoff have come increasingly early in the water year in many basins in northern and central California. This subtle trend is most pronounced in moderate-altitude basins, which are sensitive to changes in mean winter temperatures. Such basins have broad areas in which winter temperatures are near enough to freezing that small temperature increases result initially in the formation of less snow and eventually in early snowmelt. In moderate-altitude basins of California, a declining fraction of the annual runoff has come in April-June. This decline has been compensated by increased fractions of runoff at other, mostly earlier, times in the water year. The immediate cause of the trend toward warmer winters in California is a concurrent, long-term fluctuation in winter atmospheric circulations over the North Pacific Ocean and North America that is not immediately distinguishable from natural atmospheric variability. The trend is associated with interdecadal variations of the North Pacific climate system and, possibly, with long-term changes in the tropical Pacific. Because the longer low-flow seasons that follow the earlier snowmelts allow San Francisco Bay to become saltier, timing of the Sierra Nevada snowmelt and runoff influences the salinity of the bay and, thus, if sustained in the future, would provide an important part of the climatic background upon which CALFED efforts will be superimposed.

SUBSIDENCE AS RELATED TO WATER-SUPPLY VULNERABILITY IN THE SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA

Steven J. Deverel*

HydroFocus, Inc., P.O. Box 2401, Davis, CA 95617
Phone: 530-756-2840, Fax: 530-756-2687, e-mail: h2ofocus@davis.com

Since 1930, over 50 Delta islands or tracts flooded primarily the result of levee foundation instability. By reducing the landmass supporting levees, historical subsidence of Delta organic soils contributed substantially to this levee instability. Continuing subsidence can increase water supply vulnerability and levee instability by (1) increasing the volume of an island that can flood upon levee failure and (2) increasing seepage onto islands. Subsidence mitigation will increase levee stability in the Delta. This requires definition of rates and causes of subsidence, methods for stopping subsidence and accreting the land surface, and identification of priority areas for mitigating subsidence. By (1) quantifying the causes and rates of subsidence from available data, (2) evaluating methods for stopping subsidence and accreting the land surface and (3) by delineating priority areas for subsidence mitigation, we present a framework and underpinnings for subsidence mitigation in the Delta.

We used a computer model to synthesize and integrate the available data for subsidence rates and causes. The model results compared favorably with measured elevation changes. Our results indicate the major cause of present-day and historical subsidence is oxidation of organic carbon; oxidation causes over 50% of historical subsidence and over 70% of present-day subsidence. Historic subsidence since the early 1900s ranged from about 0.5 to over 4 inches per year. Mitigating subsidence relies on reducing microbial oxidation through flooding. Using a geographic information system (GIS) to integrate and analyze existing data, we identified key areas for subsidence mitigation in the western and central Delta where substantial peat remains and historical subsidence rates were high. Key necessary data for developing future subsidence mitigation strategies include (1) present-day subsidence rates, (2) effects of present-day and future subsidence on levee stability and 3) long-term rates for reversing the effects of subsidence.

BEDFORM MOVEMENT IN THREEMILE SLOUGH NEAR SAN JOAQUIN RIVER

Randal L. Dinehart*

U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA 9581
Phone: 916-278-3175, e-mail: rldine@usgs.gov

The Sacramento and San Joaquin rivers are connected ahead of their confluence by a narrow channel, the naturally formed Threemile Slough. To follow the transport pathways of sandy bed material from the lower Sacramento River, bedforms have been mapped periodically since 1998 in a 0.5 km reach at the south end of the slough where a sand shoal forms at the entrance to the San Joaquin River. A gaging station at the slough is operated by the U.S. Geological Survey to record water stage and tidal velocity.

Various types of bedforms have been surveyed to document sand movement in the tidal environment over periods of weeks and months. Sand dunes migrate throughout the surveyed reach, with heights often exceeding three meters, indicating high transport rates and substantial roughness effects on the flow. Although individual dune profiles in the reach are mostly symmetrical, dunes nearer the shoal have slipfaces at their south end, indicating southward migration of bedforms. Northward-oriented bedforms at the west side of the surveyed reach usually coexist with southward-oriented bedforms at the east side. As seen in planform, crests of the largest dunes are diagonal, not perpendicular, to the channel banks. The diagonal orientation is a consequence of bidirectional migration in the reach during dry seasons. However, bedforms across the slough were all migrating southward during high discharges from the Sacramento River in February 2000. A bedform-transport rate of 100 tonnes/day toward the San Joaquin River was calculated for the period February 18-25, 2000. Tidal flows in Threemile Slough move south into the San Joaquin River during flood tide, allowing sediment transported from the Sacramento River to become available for movement in the San Joaquin River.

EFFECTS OF SOIL ENRICHMENT AND SURFACE LITTER (MULCH) ON PICKLEWEED ESTABLISHMENT DURING MARSH RESTORATION

Michele Disney[*] and A.K. Miles

U.S. Geological Survey, Biological Resources Division, Davis Field Station; 1 Shields Avenue, 278 Kerr Hall, University of California, Davis, CA 95616-5224, Phone: 916-498-1745, e-mail: mmdisney@ucdavis.edu

With more than 90% of San Francisco Bay Area marshes already lost, effective restoration techniques are essential conservation strategies that also benefit adjacent deep water and upland ecosystems. Two revegetation techniques for establishing pickleweed (*Salicornia virginica*) were investigated at two former vehicle parking lots along Suisun Bay and at a former dumpsite on Mare Island. Enhancing the speed with which pickleweed could be established on the sites was an important objective for the research. Pickleweed was of particular interest along Suisun Bay because salinity regimes there make the area somewhat ecotonal for it. Pickleweed also provides important cover and trophic support for rare species that occur at both locations. Study sites were prepared by removing refuse or asphalt, then mechanically grading and contouring to elevations and topography appropriate for high intertidal marsh establishment. The vegetation techniques investigated were laying pickleweed on the soil surface ("mulching with pickleweed") and enriching the marsh soil with composted plant material. Vegetation and soil characteristics were monitored to observe responses to the treatments. Preliminary results suggest that timing is important to ensure effectiveness of revegetation treatments. Another possible result is that enriching the soil may have actually reduced pickleweed establishment rather than enhancing it. Microtopography seems to have had a major effect on marsh plant community development at the sites, including the establishment of pickleweed.

BIOPHYSICAL MONITORING OF WETLAND RESTORATION AND REHABILITATION PROJECTS IN SAN PABLO BAY

Giselle T. Downard[*1], J.Y. Takekawa[1], M.A. Bias[2], and L.M. Vicencio[3]

[1]**U.S. Geological Survey, Western Ecological Research Center, San Francisco Bay Estuary Field Station, P.O. Box 2012, Vallejo, CA 94592, Phone: 707-562-2000, Fax: 707-562-3001, e-mail: gdownard@usgs.gov**

[2]**ECORP Consulting, 2260 Douglas Boulevard, Suite 160, Roseville, CA 95661**

[3]**U.S. Fish and Wildlife Service, San Pablo Bay National Wildlife Refuge, P. O. Box 2012, Vallejo, CA 94592**

The numerous wetland restoration and rehabilitation projects planned in San Francisco Bay over the next decade will determine the landscape in the estuary through the next century. Although wetland restoration in baylands is a relatively new science, few studies have examined restoration processes or determined rates of success. Biophysical monitoring before, during, and after a project provides critical information for adaptive management. We provide monitoring examples from two projects in San Pablo Bay: the Cullinan Ranch restoration (606 ha) and Tolay Creek (176 ha) rehabilitation. Cullinan Ranch was formerly a large oat-hay field which had subsided 2 meters. Farming and pumping ended in 1994, and the area rapidly transitioned to a diverse seasonal wetland community. We monitored the transition from highly acidic (pH = 3.3) water conditions leading to a dramatic increase in cattail (*Typha latifolia*), use by 16 new species of waterbirds, and detection of endangered salt marsh harvest mice (*Rheithrodontomys raviventris*, SMHM) in 5% of captures. In contrast, Tolay Creek was rehabilitated from a degraded wetland strip constricted between levees with limited tidal exchange. Pickleweed (*Salicornia virginica*) dominated the lower section, but weedy species such as dock (*Rumex crispus*) and prickly lettuce (*Lactuca serriola*) covered the upper section before rehabilitation in December 1998. Pre-project surveys showed that pH increased from the bay edge, reflecting limited tidal exchange and soil oxidation in the upper reach. SMHM represented 25.3% (46 of 182) of individuals captured, many in the upper section. Post-project water levels exceeded expectations, and tidal dataloggers were used to show that flow was constricted in the upper section. Corrective channel repairs were completed in February 1999, and tidal datum documented the improvement. Small mammal populations in the upper section were temporarily displaced, but bird populations responded quickly to new areas of open water, and weedy plants were inundated.

APPLICATION OF MODELS FOR PLANNING CONTROLLED LEVEE BREACHES IN TIDAL WETLAND RESTORATION PROJECTS

Christopher Enright*

California Department of Water Resources, 3251 S Street, Sacramento, CA 95816,
Phone: 916-227-7521, Fax: 916-227-7554, e-mail: cenright@water.ca.gov

Breaching levees for tidal wetland restoration is an important issue for ecosystem restoration activities of the CALFED Bay-Delta Program. Recent modeling and analysis by the CALFED Suisun Marsh Levee Team revealed significant hydrodynamics and salinity impacts from controlled and uncontrolled levee breaches in the Suisun Marsh and Delta. Results indicate that large uncontrolled levee breaches along energetic channels can increase salinity widely in Suisun Bay and the Delta. In contrast, carefully located small breaches can produce significant salinity reductions. Levee breaches affect the physical balance between dissipation of tidal energy (tends to reduce salinity mixing), and tidal trapping of salt (tends to increase salinity mixing). How the balance manifests depends on breach location and geometry.

This talk addresses four issues for consideration as specific tidal wetland restoration projects (via levee breaches) are proposed.

1. Resolution of models used for planning.

2. Availability and accuracy of land elevation data.

3. Cumulative impacts of tidal wetland restoration initiatives and the need for coordination.

4. Sensitivity of salinity response to sedimentation and plant succession.

Implicit in these issues is the accuracy of models used to assess salinity impact sensitivity. Once levees are breached in the field, comparison of salinity impacts with the no-project scenario is difficult. Models will therefore be the primary tool to assess salinity impacts and optimize levee breach design. The presentation will conclude with a recommendation to convene a CALFED review panel in coordination with the Bay-Delta Modeling Forum to guide review and application of models in planning controlled levee breaches for tidal wetland restoration projects in the San Francisco Estuary.

INTERAGENCY TEAM CALIBRATION, VERIFICATION, AND APPLICATION SPECIFIC VALIDATION OF THE DSM2 MODEL

Christopher Enright[*1] **and R. Oltmann**[2]

[1]**California Department of Water Resources, 3251 S Street, Sacramento, CA 95816, Phone: 916-227-7521, Fax: 916-227-7554, e-mail: cenright@water.ca.gov**

[2]**U.S Geological Survey, Placer Hall, 6000 J St., Sacramento, CA 95819**

Interagency Team Calibration, Verification, and Application Specific Validation of the DSM2 Model Chris Enright, DWR The Interagency Ecological Program DSM2 Project Work Team (Team) has completed and enhanced calibration, verification, and validation of the DSM2 model. DSM2 is a one-dimensional four-point finite difference hydrodynamics and Lagrangian transport model modified for Suisun Bay/Marsh, and the Sacramento-San Joaquin Delta by DWR. The Team collaborated on numerics review, field flow and bathymetry data collection, testing, sensitivity analysis, calibration protocols, web-based output, and continuous calibration progress via a web site and email reflector.

The Team is also preparing a “model application guide” to assess model accuracy and error bounds under various modes and time/space scales of application. Some planning and operation applications of the model include:

- Analysis of sub-tidal time scale flow and water level impacts from structural modification of the Delta
- Analysis of over-year flow and salinity trend impacts from alternative statewide reservoir operations
- Historical period simulation for training artificial neural networks for carriage water analysis
- Forecasting (about two-week) impacts of water project operations on salinity, water levels, and biota

The guide is intended to provide model users and decision-makers an indicator of model efficacy for often used planning and operations analysis.

The Team effort was a unique interagency collaboration on calibration of a complex hydrodynamics and water quality model. The benefits of this cooperative effort are great because (1) a more accurate (and therefore useful) model has been created, (2) significant trust and understanding has been generated for the model among modelers, planners, operators, and stakeholders.

DIET SHIFT IN FISHES OF THE SACRAMENTO-SAN JOAQUIN ESTUARY FOLLOWING THE INVASION OF *POTAMOCORBULA AMURENSIS*

Frederick Feyrer[*1] and Scott A. Matern[2]

[1]**California Department of Water Resources, Environmental Services Office, 3251 S Street, Sacramento, CA 95816, Phone: 916-227-2552, Fax: 916-227-7554, e-mail: ffeyrer@water.ca.gov**

[2]**Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, 1 Shields Ave., Davis, CA 95616**

Ballast water exchanges in the Sacramento-San Joaquin Estuary, California, have resulted in numerous species introductions, most notably the Asian clam *Potamocorbula amurensis*. This introduction has been linked to dramatic declines in phytoplankton and many native invertebrates (e.g. the mysid shrimp, *Neomysis mercedis*), irreversibly altering the estuarine food web. To determine the trophic effects of the recent changes in invertebrate abundance, we examined the food habits of five resident fishes of Suisun Marsh from March 1998 through January 1999; splittail (*Pogonichthys macrolepidotus*), tule perch (*Hysterocarpus traski*), prickly sculpin (*Cottus asper*), yellowfin goby (*Acanthogobius flavimanus*) and striped bass (*Morone saxatilis*). We compared our results to those observed in a similar study completed in 1983, prior to the *P. amurensis* invasion. The most important prey items (frequency of occurrence and percent of total prey mass) included amphipods (*Gammarus* and *Corophium*), fish (*Gasterosteus aculeatus*), annelids, and mysid shrimp (*Neomysis mercedis* and *Acanthomysis bowmani*).

Compared to the previous study, mysid shrimp significantly declined in dietary importance in all five fishes, reflecting their sharp decline in abundance throughout the Sacramento-San Joaquin Estuary. The declines were so dramatic (up to 98% of total prey mass) that mysid shrimp were almost eliminated from the diet of each species. However, it does appear that the fishes we examined have successfully exploited alternative prey because feeding incidence, stomach fullness, and body condition were either similar in each study, or their differences were easily explained.

WATERFOWL ECOLOGY RELATIVE TO RECENT HABITAT CHANGES IN THE CENTRAL VALLEY OF CALIFORNIA

Joseph P. Fleskes[*1], M.L. Cassava[1], D.S. Gilmer[1], J.G. Mensik[2], M.R. Miller[1], D.L. Orthmeyer[1], J.Y. Takekawa[1], J.L. Yee[1], and D.R. Yparraguirre[3]

[1]**U.S. Geological Survey, Dixon Field Station, 6924 Tremont Road, Dixon, CA 95620, Phone: 707-678-0682x628 email: joe_fleskes@usgs.gov**

[2]**U.S. Fish and Wildlife Service, Willows, CA**

[3]**California Department of Fish and Game, Sacramento, CA**

During the last decade, changing agricultural practices and conservation programs such as the Central Valley Habitat Joint Venture (CVHJV) have altered the landscape of the Central Valley of California, one of the most important waterfowl wintering areas in the world. To measure the response of wintering waterfowl to these habitat changes and aid CVHJV planning, we studied waterfowl distribution, movements, habitat use and survival throughout the Central Valley during September-April, 1998-2000, by conducting monthly aerial waterfowl surveys and tracking radio-tagged pintails, mallards and white-fronted geese. Data collected during the current study will be compared with similar data collected before recent habitat changes. Preliminary results indicate that the ecology of waterfowl wintering in the Central Valley has changed over the last decade and CVHJV habitat goals may require modification. This project is a cooperative effort of the California Department of Fish and Game, California Waterfowl Association, Central Valley Habitat Joint Venture, Ducks Unlimited, Inc., Grassland Water District, The Rice Foundation, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service and U.S. Geological Survey.

RESTORATION OF FLOODPLAIN GEOMORPHOLOGY AT INTENTIONAL LEVEE BREACHES

Joan L. Florsheim* and J.F. Mount

Department of Geology and Center for Integrated Watershed Science and Management, University of California, Davis, 1 Shields Ave., Davis, CA 95616
Phone: 530-752-0350, Fax: 530-752-0951, e-mail: florsheim@geology.ucdavis.edu

Restoration of floodplain geomorphology at intentional levee breaches is dependent on accommodation of fundamental processes such as flooding, erosion, transport, and deposition that are essential for diversity in floodplain ecology. Levees constructed over the past century in the lowland Cosumnes River, Central Valley, California, have changed floodplain habitat by isolating the river from its floodplain and by inhibiting these geomorphic processes. Additionally, agricultural draining, leveling, and clearing of riparian vegetation reduced the geomorphic complexity associated with the pre-disturbance anastomosing system that included topographically low seasonal marshes, channels, and perennial lakes, and topographically higher splays and levees. As part of a long-term interdisciplinary ecosystem monitoring project, we are investigating two intentional levee breaches constructed to restore floodplain habitat in portions of the Cosumnes River Preserve. Levee breaches at the "Accidental Forest" (1995) and the "Corps Breach" (1997) floodplain areas restored connectivity between the main channel and floodplain. Field surveys document the morphology of sand splays that formed on the formerly flat agricultural fields at the levee breach floodplain restoration areas. Floodplain sand splay deposition (up to 0.5 m) and erosion (up to 0.8 m) patterns and progradation of splay channels (up to 30 m) illustrate the first phase in the evolution of floodplain morphology needed to restore diversity to the former agricultural field and to accommodate geomorphic processes. Initial grading inside the breach such as an excavated pond and setback levee inhibits geomorphic processes. Continued monitoring of geomorphic changes and their association with vegetation establishment at these intentional levee breaches will provide further information to help define a scientific basis for sustainable floodplain river restoration.

TOOLS FOR IDENTIFYING SOURCES OF PROBLEMATIC NATURAL ORGANIC MATTER IN SACRAMENTO-SAN JOAQUIN DELTA WATERS

Miranda S. Fram* and B.A. Bergamaschi

U.S. Geological Survey, Placer Hall, 6000 J Street, Sacramento, CA 95819-6129
Phone: 916-278-3088, Fax: 916-278-3071, e-mail: mfram@usgs.gov

CALFED seeks to restore Delta ecosystems while also improving the quality of drinking water derived from the Delta. Improving water quality requires mitigation of the problematic fraction of natural organic matter (NOM) that reacts during water treatment to form hazardous byproducts, such as trihalomethanes (THM). However, the Delta is a large and complex system, making identification of sources of this problematic NOM an expensive and time-consuming task. We can learn about the processes involved in production of NOM through study of analogous systems, such as Sweetwater Reservoir in metropolitan San Diego, that have important features in common with the Delta, but are small and simple enough that contributions from various sources can be quantified. Both Delta and Sweetwater Reservoir waters receive inputs of NOM from wetland vegetation, riparian zones, primary productivity, urban runoff, and organic-rich soils, and both contain concentrations of NOM and bromide that result in high levels of THM during treatment.

We are quantifying the contributions of NOM from these sources to Sweetwater Reservoir, and then using similar approaches to identify contributions from analogous sources to Delta waters. For example, once a year, water flows down the Sweetwater River from an upstream reservoir and doubles the volume of Sweetwater Reservoir. We found that 12% excess NOM was swept out of the riparian zone along the river during this event and that 18% excess NOM was released from the newly flooded region of Sweetwater Reservoir. NOM released from organic-rich soils and wetland vegetation in the newly flooded region had a distinct composition and reacted rapidly to form THM. NOM swept from the riparian zone reacted less rapidly, and NOM in urban runoff had the slowest reaction rates with respect to THM formation. THM formation kinetics has also proved useful in determining NOM sources in Delta waters.

RESULTS ON THE EFFECTS OF CONSTRUCTED WETLANDS FOR SUBSIDENCE MITIGATION ON DRINKING-WATER QUALITY, SACRAMENTO-SAN JOAQUIN DELTA

Roger Fujii[*1], B.A. Bergamaschi[1], M.S. Fram[1], G.R. Aiken[2]

[1]**U.S. Geological Survey, 6000 J St., Sacramento, CA 95819-6129**
Phone: 916-278-3055, Fax: 916-278-3071, e-mail: rfujii@usgs.gov

[2]**U.S. Geological Survey, 3215 Marine St., Boulder, CO 80303**

Water exported from the Sacramento-San Joaquin River Delta supplies drinking water to more than 22 million people in California. Delta waters contain elevated concentrations of dissolved organic carbon (DOC) and bromide that, when chlorinated, can exceed the USEPA's maximum contaminant level for trihalomethanes (THMs) of 0.080 mg/L. Important sources of DOC and THM precursors to the Delta include rivers, drainage from peat islands, water from wetland and riparian habitats, and in-channel primary production. Considerable effort is focused on restoring wetland habitat and mitigating subsidence in the Delta. We have been conducting research on the use of wetland habitats to mitigate subsidence. One focus of our research is on how the concentration and quality of DOC (THM precursors) in drainage water change when subsided peat soils are converted from agriculture to wetlands. Results from ongoing studies on Twitchell Island investigating the effects of constructed wetlands and agricultural operations on drainage water quality show that the median concentrations of DOC and THM formation potential (THMFP) decrease in the order: shallowly flooded wetlands agricultural field open-water wetland. In contrast, the median specific THMFP (THMFP/DOC), a measure of the propensity of the carbon to form THMs and an indicator of carbon quality, decrease in the order: open-water wetland shallowly flooded wetlands agricultural field. By comparison, median DOC, THMFP, and STHMFP for waters from the Sacramento and San Joaquin Rivers were all much lower. These results clearly indicate that (1) the quality of DOC needs to be assessed because different sources and biogeochemical processing results in DOC with significantly different propensities to form THMs, and (2) the loads of DOC and THM precursors resulting from different land uses need to be determined to evaluate the relative contributions of these land uses on the quality of drinking water diverted from the Delta.

LONG-TERM TRENDS IN FISH SALVAGE: DIFFERENCES BETWEEN FACILITIES

Robert Fujimura*

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: bfujimur@delta.dfg.ca.gov

The Central Valley Project's Tracy Fish Collection Facility (TFCF) and the State Water Project's John Skinner Fish Protective Facility (SFPF) are the two largest fish screening and transport facilities in the Sacramento-San Joaquin Delta. The TFCF was constructed in the mid-1950s by the U.S. Bureau of Reclamation, uses a louver (behavioral) screening system and receives water directly from Old River channel. The SFPF was built in the late 1960s by the Department of Water Resources and used a similar louver screening system to remove fish entrained from Old River via Clifton Count Forebay, a large stage regulation reservoir. Despite the close proximity of their intakes, past investigations have found that the seasonal (intra-annual) trends for salvaged fish were often not highly correlated between facilities. I examined the occurrence and abundance trends of selected native and non-native fish salvaged (sampled) during the last 21 years of operation (1979 to 1999). The inter-annual salvage indices for each facility were compared and emphasis was given to examining their similarity and determining their overall trends. This has direct implications for water project operations, such as the use of Joint Point diversions.

HUDSON RIVER AQUATIC FILTER BARRIER TEST AND PROPOSED AFB DEPLOYMENT TEST AT SOUTHERN ENERGY DELTA, LLC. CONTRA COSTA POWER PLANT, ANTIOCH, CALIFORNIA

Steven A. Gallo*

Southern Energy California, P.O. Box 192, Pittsburg, CA 94565
Phone: 925-427-3513, Fax: 925-427-3511, e-mail: sagallo@seiworldwide.com

A key item of the CALFED program is to reduce take of species within the Delta by the installation of new screen facilities for water intakes. The CALFED EIR identifies the water withdrawals for the once through cooling water systems at the Pittsburg and Contra Costa Power Plants as significant locations to be addressed. These power plants were purchased by Southern Energy California (SE) from PG&E in April 1999. SED is proposing to perform a demonstration of a new type of screen technology at the Contra Costa Power Plant in 2001 called an aquatic filter barrier.

SED proposes to install, on a test basis, an aquatic filter barrier, the Gunderboom, Inc. Marine/Aquatic Life Exclusion System (MLES^{tm}), at the Contra Costa Power Plant. The AFB consists of non-woven matting of polypropylene and polyethylene fibers that are sewn together in two layers making vertical panels approximately 8-foot wide along the 1700 foot length of the barrier. The barrier is suspended in the water with a flotation billet system on the surface and secured to the river bottom with anchoring devices that seal, achieve the shape that is desired, and hold the boom against the current forces in the river. The system is planned to pass water through the fabric itself and through 3/32-inch holes with an anticipated through barrier flow rate of 0.02 feet per second.

SIERRA NEVADA SNOWPACK—THE CRUCIAL SOURCE OF FRESHWATER TO SAN FRANCISCO BAY

Frank Gehrke[1], Dan Cayan[2,3], and Maury Roos[4]

[1]**Director, California Cooperative Snow Surveys, California Department of Water Resources, P.O. Box 219000, Sacramento, CA 95821-9000, Phone: 916-574-2635, e-mail: gridley@water.ca.gov**

[2]**Scripps Institution of Oceanography, UC San Diego, La Jolla, CA**

[3]**U.S Geological Survey**

[4]**California Department of Water Resources, Sacramento, CA**

The amount of water accumulated in the Sierra Nevada is the major contributor to fresh water feeding the San Francisco Bay-Delta. Snow accumulation in the high Sierra usually reaches its apex around late March or early April, but from year to year, the timing changes by weeks and the maximum accumulation often varies from its long-term average by +/- 50%. With a substantial fraction of its snow covered area in the watershed lies in the moderate elevation zone that would be vulnerable to any future increases in temperature, global climate change could produce a marked decrease in the natural storage that is provided by the seasonal Sierra snowpack. A critical observational program is the California Cooperative Snow Surveys, which maintains a network of over 300 human-observed snow courses and over 100 automated recording snow sensors. A comprehensive effort to gage the snow accumulation in California by measuring the depth and water content of the snow in a set of regularly monitored snow courses begun in 1929, provoked by the threat of drought and the need to survey the volume of runoff that could be expected from the snowpack. Continuously recording snow sensors have been introduced more recently, generally beginning in about 1980. Very large Sierra snow accumulation years such as 1952 and 1983, and very poor snow accumulation years such as 1977 and 1988 were associated with persistent, large scale climate anomalies. Operation of the California snow surveys program is reviewed and the climate variability that is recorded in these observations is highlighted.

THE YELLOW-BILLED CUCKOO: A RIPARIAN SPECIES OF CONCERN IN CALIFORNIA

David Gilmer[1], M. Halterman[2], S. Laymon[3], G. Falxa[4], and J. Gustafson[5]

[1]**U.S. Geological Survey, 6924 Tremont Road, Dixon, CA 95620**
Phone: 707-678-0682, e-mail: dave_gilmer@usgs.gov

[2]**Southern Sierra Research Station, P.O. Box 1316, Weldon, CA 93283**

[3]**P.O. Box 1236, Weldon, CA 93283**

[4]**U.S. Fish and Wildlife Service, 2800 Cottage Way, Sacramento, CA 95825**

[5]**California Department of Fish and Game, 1416 Ninth Street, Sacramento, CA 95814**

The yellow-billed cuckoo is currently being considered by the U.S. Fish and Wildlife Service for listing under the Endangered Species Act. The species is presently listed as endangered by the California Fish and Game Commission. Surveys to assess the status of the yellow-billed cuckoo were conducted throughout California's riparian habitats in 1999. Major survey areas were the Sacramento, Kern, and Lower Colorado rivers and many other areas with less amounts of potential habitats. Surveys are being repeated in 2000 but the focus is primarily on habitat on the Sacramento and South Fork Kern rivers, the areas which support substantial populations. The call-playback method is used to maximize detection of this elusive and secretive bird. In 1999 we found a total of 41-45 pairs and 49 unmated birds. The majority of the sightings were on the Sacramento River (28 to 32 pairs). Comparable statewide surveys were conducted in 1977 and again in 1986-1987. The 1977 survey found an estimated 122 to 163 pairs statewide, while the 1986-1987 survey located 31 to 42 pairs. Numbers at all sites declined between 1977 and 1986-1987, with declines most remarkable along the Lower Colorado River (from 60 to 2 to 4 pairs). The number of cuckoos detected statewide remained fairly stable between 1986-87 and 1999. The South Fork Kern and Sacramento rivers are the only areas surveyed with more than 1000 ha of prime habitat. Riparian habitat at these sites is characterized by high canopy cover, a fairly extensive understory, structural diversity and functional river dynamics which maintain and renew complex riparian landscape. The decline and loss of small populations at some sites is most likely due to stochastic events. Any effort to stabilize and increase the Yellow-billed Cuckoo population in California should focus on increasing the extent and quality of the riparian habitat as well as monitoring of current and restored habitat.

SPATIAL MODELING OF EPISODIC CHANNEL MIGRATION ON THE SACRAMENTO RIVER

Steven E. Greco*

Dept. of Environmental Design, University of California, Davis,1 Shields Ave., Davis, CA 95616
Phone: 530-754-5983, Fax: 530-752-1392, e-mail: segreco@ucdavis.edu

Infrequent, high magnitude precipitation events in northern California are often associated with increased flows and increased rates of channel migration on the Sacramento River. Annual hydrographs of discharge data (Q) recorded daily at gage stations reveal the pulsed nature of these event driven flows. A flow analysis was conducted at the Vina gage (river mile 218.5) to quantify the relative magnitude of flows on an inter-annual basis using hydrograph data compiled from 1952-1997. Each water year's hydrograph was evaluated for the duration (number of days) and intensity (recurrence interval) of flow to calculate a flow magnitude index score. The highest scores were classified as "event" years. Following this, each event year's relative contribution to potential channel migration was computed as a proportion between an individual event year's score and the sum total of all event scores. "Non-event" years were assumed not to significantly contribute to channel migration. Plan form maps of channel alignment for the years 1952, 1966, 1978, 1987, and 1997 were digitized from aerial photo data, entered into a GIS, and then linearly morphed in sequential pairs of years (e.g., 1952 to 1966, 1966 to 1978, etc.). To illustrate the pulsed or episodic nature of inter-annual channel migration events, an animation of the spatial modeling results will be shown and contrasted with linear channel migration.

CONTRASTS IN FISH, BENTHIC INVERTEBRATE, AND INSECT SSEMBLAGES AT BREACHED-LEVEED AND REFERENCE WETLANDS IN THE SACRAMENTO SAN JOAQUIN DELTA

Lenny F. Grimaldo*[1], R.E. Miller[1], C.M. Peregrin[1], Z. Hymanson[1], C.A. Simenstad[2], and J.D.Toft[2]

[1]**California Department of Water Resources, 3251 S Street, Sacramento, CA 95816**
Phone: 916-227-0178, e-mail: lgrimald@water.ca.gov

[2]**School of Fisheries, University of Washington, Seattle, WA 98195-5020**

The objective of this study was to examine fish and invertebrate communities at breached-leveed and natural ("reference") tidal freshwater wetlands in the Sacramento-San Joaquin Delta. We sampled four reference sites and six breached-levee sites 17 to 75 years post levee-breach between April 1998 and July 1999. Indicators of benthic invertebrate and insect assemblages in emergent marsh habitats were typically less comparable to reference marshes for the most recently breached site, while older restored sites were more similar. Introduced species (fish and invertebrates) were the dominant organisms collected at most study sites. The spatial and temporal variability of fish communities along subtidal and intertidal margins did not correspond to site age. Canonical correspondence analysis indicated fish species composition was most significantly associated with submerged aquatic vegetation and temperature. While there were no distinct trends in sources of fish prey among restoring sites of different ages and the reference sites, fish at one of the reference sites and at older breached-levee sites tended to consume more benthic and epibenthic prey while fish at one of the younger wetland sites consumed more zooplankton. We conclude the age of a restored wetland is probably not reliable indicator of whether certain fish assemblages (e.g., native fishes) will eventually re-colonize a restored wetland. Other ecosystem attributes, such as invertebrate prey resources, may better demonstrate progressive restoration. The Sacramento-San Joaquin Delta is highly modified and introduced species may inhibit the restoration of natural ecosystem functions and native fishes.

THE POTENTIAL IMPACTS OF THE EUROPEAN GREEN CRAB ON ESTUARINE RESTORATION

Edwin D. Grosholz*

Dept. of Environmental Science and Policy, University of California, 1 Shields Ave., Davis, CA 95616
Phone: 530-752-9151, Fax: 530-752-3350, e-mail: tedgrosholz@ucdavis.edu

Restoration projects in the San Francisco Bay-Delta region must necessarily consider the consequences of restoration on the relative abundance of non-indigenous vs. indigenous species. Some species may have particularly strong impacts on native species, and may negatively influence the value of restored habitats. The European green crab, *Carcinus maenas*, was accidentally introduced into San Francisco Bay around 1989-90, and this euryhaline species can be found throughout most of the Bay. Our work in nearby Bodega Harbor has documented dramatic impacts of the green crab on several native species including 90% to 95% reductions in small bivalves and shore crabs. Previous studies in both native and exotic habitats have shown that green crabs can negatively affect a wide range of native species. The depletion of important native invertebrate species may also have long-term consequences for wintering shorebirds in San Francisco Bay. In addition, green crabs may also disrupt the restoration process itself by damaging outplanted seagrasses used for restoration. While we know certain features of restored estuarine habitats may make them particularly susceptible to colonization by large numbers of green crabs, much more attention must be directed towards understanding how to restore estuarine habitats throughout the Bay so as to minimize the impacts of alien predators.

SMALL-SCALE SPATIAL VARIATION IN RESIDENCE TIME INFLUENCES LOWER TROPHIC LEVELS ON A COSUMNES RIVER FLOODPLAIN

Edwin D. Grosholz*, A. Mueller-Solger, and K. Forshay

Dept. of Environmental Science and Policy, University of California, 1 Shields Ave., Davis, CA 95616
Phone: 530-752-9151, Fax: 530-752-3350, e-mail: tedgrosholz@ucdavis.edu

Among the many ecosystem benefits of restoring river floodplains is the presumed creation of habitats that will support productive populations of native fishes and invertebrates. To achieve this goal, there must be appropriate seasonal inundation of the floodplain, but also significantly high residence time of the floodplain water mass. In this study, we investigate variation in residence time over relatively small spatial scales on a seasonal floodplain of the Cosumnes River and determine the consequences of this variation for the abundance and biomass of zooplankton and phytoplankton. Assuming that higher temperature and lower flow velocity of the water column is correlated with higher residence time, we found striking variation in residence time within a flooded fields over distances of a few hundred meters. These physical differences were strongly correlated with significant differences in the abundance and biomass of zooplankton. Sites with longer residence times had higher abundances of large cladocerans, calanoid copepods, and greater algal biomass relative to sites with shorter residence times. These small-scale spatial differences in physical parameters and organismal abundance were maintained for several weeks. We also investigated this small-scale spatial variation in residence time on zooplankton growth in laboratory experiments. We conducted feeding bioassays using *Daphnia* to compare growth rates in water fractions collected from sites with different residence times under standard culture conditions. Daphnia growth rates were significantly greater in water taken from in sites with higher residence times relative to sites with lower residence time that were closer to the river spillover. The measured growth rates were closely correlated with other measured biological parameters including phytoplankton biomass indicating the availability of suitable food resources. Our work highlights the importance of considering small-scale variation in floodplain hydrology in evaluating restoration success.

INVASIVE PLANT DYNAMICS IN MARSHES FOLLOWING TIDAL ENHANCEMENT

Laura A Hanson*, K.P. Malamud-Roam, and A.M. Brown

Contra Costa Mosquito and Vector Control District, 155 Mason Circle, Concord, CA 94520
Phone: 925-685-9301 ext. 119, Fax: 925-685-0266, e-mail: pipefish@earthlink.net

The invasive nonnative shrub *Lepidium latifolium* is reported to be spreading along tidal channels and adjacent moist uplands in Suisun Marsh and other parts of the San Francisco Bay and Delta. It competes with moist upland vegetation typical of levee berms and other wetland species such as Salicornia virginica, *Atriplex triangularis* and *Juncus balitcus*. *Lepidium latifolium* has been carefully monitored since 1991 at the Point Edith Marsh Complex, south of Suisun Bay. Before project activities, a history of diking had lead to subsidence, poor tidal circulation, and poor drainage throughout most of the marsh complex. A significant decline was observed in *L. latifolium* cover from 1991 to 1995 following Phase I tidal restoration to the northwestern portion of the marsh. Phase I coincided with unusually dry winters. The 1997 Phase II tidal restoration coincided with unusually wet winters and the decline in *L. latifolium* cover was far less than significant.

RESTORATION OF DELTA FLOODPLAIN TERRACES THROUGH BIOENGINEERING

Jeffrey A. Hart* and J. Hunter

Habitat Assessment and Restoration Team, Inc., 13737 Grand Island Road, Walnut Grove, CA 95690
Phone: 916-775-4021, Fax: 916-775-4022, e-mail: jhart@ns.net

Riverbank and nearshore environments of the Sacramento-San Joaquin Delta are degraded due to past reclamation, ongoing maintenance and flood control activities, change of flow and sediment regimes, and recreational boating. Less than 10% of natural, earthen riverbanks now exist in the Delta, with the majority of the sites having received rock revetment for levee and bank protection. Under the auspices of a 1997 CALFED award, an erosion control/restoration project was launched in the summer of 1999 along Georgiana Slough. The goal of this project is to provide levee protection by biotechnical means that would also create habitat. We hypothesized that winter sediment transport would provide the sediment and biotechnical structures would prevent its loss during the summer boating season. This scenario was evaluated through a factorial experiment involving 50 sites. The factors were scallop type and treatment. Using multivariate statistics, sites were classified on the basis of various morphmetric variables, reach location, and bendway position. Of the 50 sites, two-thirds were treated with biotechnical methods, and the remaining one-third left as control or do-nothing sites. To measure the relative deposition and erosion at the sites, more than 1800 erosion pins were randomly placed at both treatment and control sites. This past winter, sediment accumulated at both control and treated sites. Mean sediment depth in April 2000 was 14 ± 1 cm at control sites (n = 19) and 17 ± 1 cm at treated sites (n = 31). Since April, however, control and treated sites have differed significantly in the retention of this sediment (P < 0.0001). As of early June, 70% of sediment had been removed from control sites (June mean 4 ± 1 cm) while treated sites gained several millimeters of additional sediment. These results demonstrate the effectiveness of biotechnical bank protection in this setting.

GENETIC DIVERSITY AND STRUCTURE OF CHINOOK SALMON POPULATIONS IN THE CENTRAL VALLEY OF CALIFORNIA

Dennis Hedgecock*, M.A. Banks, V.K. Rashbrook, and C.A. Dean

Bodega Marine Laboratory, University of California, Davis, 2099 Westside Rd., Bodega Bay, CA 94923-0247, Phone: 707-875-2075, Fax: 707-875-2009, e-mail: dehedgecock@ucdavis.edu

Conservation of protected chinook salmon stocks in the Central Valley requires an ability to discriminate them from non-protected populations, at all stages in the life cycle. A set of ten, highly polymorphic microsatellite DNA markers was developed and surveyed in more than 2300 fish collected from 41, naturally spawning and hatchery stocks of the winter, spring, fall, and late-fall runs, from 1991 through 1997. Except for the discovery of two distinct lineages of spring run, observed genetic divergence among spawning runs accords well with life history. Winter run is the most distinct subpopulation in the Central Valley, perhaps because it suffered a bottleneck in population size. Next most distinctive are the spring runs in Butte Creek and in Deer and Mill creeks. Fall and late-fall runs, the most closely related stocks, still differ significantly in genetic composition. Temporal and spatial genetic heterogeneity among samples within subpopulations is minimal, and genotypes in most samples conform to random-mating proportions. This study provides a baseline for addressing a number of conservation issues. For example, one can now accurately and precisely estimate the run-composition of mixtures of Central Valley chinook salmon, such as occur in the Sacramento-San Joaquin Delta or in California's ocean fisheries. This is affirmed both by computer simulations and by concordance among microsatellites, allozymes, and coded-wire tag recoveries in partitioning an experimental ocean catch. Further, microsatellite markers and baseline data permit assignment of individuals either to winter run or to non-winter runs; work on similar assignment for spring run, using new microsatellite markers, is in progress. Accuracy of genetic assignments is being improved by taking into account the run-composition of samples. Individual assignment of salvaged smolts reveals the inaccuracy of current methods for estimating winter-run take in the Delta. Individual assignment also prevents run-admixture and hybridization in the winter-run hatchery program.

FISH COMMUNITIES OF SAN FRANCISCO BAY TIDAL MARSHES

Kathryn Hieb* and T. Greiner

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: khieb@delta.dfg.ca.gov

A variety of San Francisco Bay tidal marsh habitats in the lower Petaluma River and northern Napa-Sonoma Marsh were sampled for fishes, shrimps, and crabs from 1995 to 1999. Adjacent deep water habitats, such as the Petaluma River and Napa Slough, were also periodically sampled. Because no one gear type was used to sample all habitats, quantitative comparisons were difficult. Instead, we used several methods to qualitatively compare fish communities from the various habitats.

In general, resident native species dominated our catches in the marsh plain channels, with a gradation to transient species, many introduced, as we moved to deeper water habitats. For example, the marsh resident threespine stickleback (*Gasterosteus aculeatus*) and longjaw mudsucker (*Gillicthys mirabilis*) accounted for 41% and 25%, respectively, of all fish collected in the lower Petaluma River marsh plain channels. However, the introduced yellowfin goby (*Acanthogobius flavimanus*) was the third most common species collected in this habitat, accounting for 23% of our catch. In adjacent deeper water, the introduced striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), yellowfin goby, and shimofuri goby (*Tridentiger bifasciatus*) were the most common species.

Several introduced species were ubiquitous; the yellowfin goby and the shimofuri goby were collected in all habitats sampled in both areas, while the inland silverside was collected in all habitats sampled in Napa Marsh and all but the marsh plain in the lower Petaluma River. The native splittail (*Pogonicthys macrolepidotus*) was collected in only one habitat, but catches were limited to years of high abundance (i.e. 1995 and 1998). Age-0 splittail comprised 12% of our lower Petaluma River and 5% of our Napa Marsh emergent vegetation catches in 1998, but were not collected in 1996, 1997, or 1999. This supports the importance of a multi-year study when determining use of tidal marsh habitats by sensitive species.

MICROBIAL DECOMPOSITION OF DELTA ORGANIC MATTER: ROLE OF PHOTO-OXIDATION

James T. Hollibaugh*, M.A. Moran, W. Sheldon, N. Bano, and R. Stepanauskas

Department of Marine Sciences, University of Georgia, Athens, GA, 30602-3636, Phone: 706-542-3016, Fax: 706-542-5888, e-mail: aquadoc@uga.edu

We measured the oxygen demand associated with microbial consumption of dissolved organic carbon sampled at several sites in the Delta chosen to represent possible CALFED rehabilitation endpoints. One goal of the investigation was to compare the bioavailability of dissolved organic carbon produced by these ecosystems. Bioavailablity was assessed before and after exposure to a measured dose of UV irradiance simulating solar spectral characteristics. We found that both bioavailability and the effect of UV radiation varied with the source of the organic matter and by season. Generally only a small percentage (<20%) of the organic matter was bioavailable in 14-day incubations and UV treatment did not greatly increase this fraction.

LEVEE STABILITY IMPACTS FROM SEEPAGE INDUCED BY DELTA ISLAND FLOODING

Edwin M. Hultgren*

Hultgren-Tillis Engineers, 2520 Stanwell Drive, Suite 100, Concord, CA 94520,
Phone: 925-685-6300, Fax: 925-685-6768, e-mail: hultgren@pacbell.net

Interior elevations on deep peat islands range from 10 to 20 feet below sea level. Most farmers and their reclamation district engineers on deep peat islands have reported seeps or wet spots at or near levees that have developed and remained continual sources of concern. Seepage has appeared following dredging in adjacent channels. Seepage has also been observed after an adjacent island's levee fails and the adjacent island floods. This seepage disappears when the adjacent island's levee is repaired and the flooded island is pumped dry. CALFED is considering water storage on islands within the Delta, potentially creating conditions similar to a flooded island.

Common stratigraphy beneath the islands in the central Delta consists of peat over sand. The sand aquifer is believed to be continuous between islands, and most certainly across man-made cuts. Flooding of a Delta island raises the head in the underlying aquifer. Lateral seepage through the aquifer can raise the groundwater level beneath adjacent islands. Flow-nets of seepage are presented. The impact of increased seepage on levee stability is discussed. Methods to control seepage are described. Sensitivity of slough bottom conditions are considered. The benefits of relief wells during flood stage are discussed.

THE BASE OF THE FOOD WEB IN THE SACRAMENTO-SAN JOAQUIN DELTA: COMPOSITION AND LONG-TERM CHANGES

Alan D. Jassby[*1] and J.E. Cloern[2]

[1]**Dept. Environmental Science and Policy, University of California, Davis, CA 95616**
Phone: 530-752-7865, Fax: 530-752-3350, e-mail: adjassby@ucdavis.edu

[2]**U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025**

The abundances of many freshwater zooplankton species have declined in the Delta over the past few decades. The cause of these population declines is still uncertain but changes in the food supply are suspected to play a role. In this talk, we focus on retrospective analyses to define the composition of the food supply and examine its long-term behavior. On a Delta-wide, annual average basis, river-borne loading is the largest source of organic carbon; phytoplankton production and agricultural drainage are secondary; wastewater treatment plant discharge, tidal marsh drainage and possibly aquatic macrophyte production are tertiary; and benthic microalgal production, urban runoff and other sources are negligible. Externally-derived dissolved organic carbon such as river-borne loading must, however, be converted to particulate form--with losses due to refractoriness and bacterial growth inefficiency--before it becomes available to the metazoan food web. When these losses are accounted for, river loading and agricultural drainage play a much smaller role, and phytoplankton production a much larger one, than is evident from a simple accounting of bulk organic carbon sources, especially in seasons critical for larval development and recruitment success. Phytoplankton-derived organic matter from upstream is also a major component of river-borne particulate loading to the Delta. Long-term trends in phytoplankton productivity and river-borne loading are described.

A PHYSICALLY-BASED WATERSHED MODEL FOR THE UPPER COSUMNES BASIN, CALIFORNIA

M. Levent Kavvas*, Z.Q. Chen, M.L. Anderson, and H. Aksoy

Hydrologic Research Laboratory, Dept. of Civil and Environmental Engineering and Center for Watershed Science, University of California, Davis, CA 95616, Phone: 530-752-2518, Fax: 530-752-7872, e-mail: mlkavvas@ucdavis.edu

The Cosumnes River watershed provides significant flows directly into the Sacramento-San Joaquin Delta and provides habitat for a variety of species. In order to provide competent management of this resource, it is necessary to understand the watershed processes that contribute to the flows in the basin. Toward this end, a physically based watershed hydrology model has been developed for the Camp Creek tributary to the North Fork of the Cosumnes River. With this model, insights are being gained into the roles played by the different physical processes that contribute flow to the stream channel. The model can also be used to assess the impact of the changes in land management to the water balances and erosion/sediment transport within the watershed. An overview of the model will be presented along with results of initial studies and an outline of future work to be conducted.

FISH TREADMILL FACILITY FOR TESTING FISH PERFORMANCE NEAR FISH SCREEN

M. Levent Kavvas and Zhiqiang Chen*

J. Amorocho Hydraulics Laboratory, 1 Shields Ave., University of California, Davis, CA 95616
Phone: 530-752-2469, Fax: 530-752-2385, e-mail: zqchen@ucdavis.edu

A Fish Treadmill facility has been constructed in the UC Davis J. Amorocho Hydraulics Laboratory. Hydraulic conditions near the fish screens in diversion structures affect fish behavior, swimming ability and performance. The purpose of the fish treadmill is to determine (1) how Delta fish species of various sizes and swimming abilities might behave if subjected to a physically screened barrier in the river and (2) suitable approach velocity, swiping velocity, and screen exposure time for various species in order to prevent the fish being injured by the screens. The Fish Treadmill apparatus is capable of providing controlled flow regimes at levels similar to those currently required for screened water diversions, in an annular swimming channel in which fish could be confined and their responses to the flow and screen observed and quantified. The treadmill is currently being used to test various Delta fish species. The design of the fish treadmill apparatus and the hydraulic conditions in the swimming channel will be shown in the presentation.

THE CURRENT STATUS AND CONSERVATION STRATEGIES FOR RARE PLANTS AND HABITATS IN THE SACRAMENTO-SAN JOAQUIN VALLEY AND DELTA

Todd Keeler-Wolf

California Natural Diversity Database, California Department of Fish and Game, 1807 13th Street, Suite 202, Sacramento, CA 95814, Phone: 916-324-6857, e-mail: tkwolf@dfg.ca.gov

Over 100 years of environmental degradation of the Valley-Delta area resulting from water diversions, intensive land clearing for agriculture, and urban development has eliminated over 90% of riparian and wetland habitats, over 90% of the native grassland stands, and over 75% of the areas' oak woodlands. The numerous endemic species of plants that evolved as components of these habitats have suffered concomitantly. In this overview, I categorize each of the state and federally recognized rare species in the context of its habitat, its current and past distribution, and efforts and stumbling blocks in conservation and recovery. The roles of habitat assessment including vegetation classification, mapping, and monitoring as well as individual species inventory and monitoring in the conservation of the areas' species are discussed. The current status of habitat and species assessment (including frequency, spatial resolution, and completeness of coverage) is compared to the predicted need to sufficiently understand the status of the species and their associated habitats. A set of recommendations are put forth that, if enacted, would provide the information needed to accurately assess the current status of the natural systems in the Central Valley and Delta and to develop a set of conservation planning tools to promote recovery of its rare species and habitats.

RIPARIAN RESTORATION SITE SELECTION

Kaylene E. Keller* and J.F. Quinn

Department of Environmental Science and Policy, University of California, 1 Shields Ave., Davis, CA 95616, Phone: 530-754-6051, Fax: 530-752-3350, e-mail: kekeller@ucdavis.edu

Prioritization of aquatic and terrestrial habitat restoration projects is a fundamental challenge to the CALFED ERP. An expert system is needed to identify and assist in restoration site selection. This system should also be available for use by watershed groups and local agencies, and be linked to CALFED's restoration activities. Frequently, restoration sites in a watershed are not coordinated or planned within the context of the overall watershed. Additionally, restoration site selection often occurs not because the site is key to meeting habitat or species conservation goals, but because a willing or cooperative landowner has been identified. This approach to site selection is ad hoc and is unlikely to meet CALFED's long-term restoration goals. In a pilot study conducted in the lower Cosumnes River basin, The California Riparian Evaluation System (CARES) was modified to address the landscape-scale information needs for selection of potential restoration sites. Relative soil moisture, depth to ground water, permeability of the soil, locations of incised channels, and levee extent were added to the restoration site selection model. This allowed identification of riparian reaches that possess attributes that indicate a high likelihood of restoration success. Using the modified CARES system, these sites can be compared on a regional scale and prioritized based on their potential relative contribution to watershed restoration goals. The lower Cosumnes River, with its extensive restoration programs, was used to calibrate and validate the model.

ALL COPEPODS ARE NOT CREATED EQUAL: EFFECTS OF THE CLAM *POTAMOCORBULA AMURENSIS* ON ESTUARINE FOODWEBS

Wim Kimmerer* and C. Peñalva

Romberg Tiburon Center, San Francisco State University, P.O. Box 855, Tiburon, CA 94920
Phone: 415-338-3515, Fax: 415-435-7120, e-mail: kimmerer@sfsu.edu

Declines in productivity at the base of the estuarine foodweb may underlie significant decreases in abundance of fishes in recent decades. We are investigating the role of the introduced clam *Potamocorbula amurensis* in altering the estuarine foodweb and possibly reducing productivity. Substantial declines in chlorophyll concentrations and abundance of estuarine copepods (*Eurytemora affinis*) in Suisun Bay, concurrent with the spread of *P. amurensis*, were previously attributed to filtration of both phytoplankton and copepod nauplius larvae by the clams. The numerically dominant copepod of the lower estuary, *Acartia* sp., declined at the same time. Our recent research suggests that this decline occurred through competition rather than predation. Nauplii of *Acartia* and of the abundant cyclopoid *Oithona davisae* have strong escape responses to predation by the clam, and may be relatively invulnerable to ingestion in clam siphons. In contrast to *E. affinis*, egg production of *Acartia* is sometimes severely food-limited; thus, it may have responded strongly to the decline in chlorophyll concentrations in the northern estuary. *O. davisae* actually increased in abundance, and may be less food-limited than *Acartia* species. We estimate that the impact of this shift in species composition on higher trophic levels could be substantial.

MODELING THE SACRAMENTO RIVER SALMON POPULATION: MODEL DESIGN AND PRELIMINARY RESULTS

Wim J. Kimmerer[*1], S. Railsback[2], S. Jackson[3]

[1]**Romberg Tiburon Center, PO Box 855, Tiburon, CA 94920**
Phone: 415-228-3515, Fax: 415-435-7120, e-mail: kimmerer@sfsu.edu

[2]**Lang, Railsback and Associates, 250 California Ave., Arcata, CA 95521**

[3]**Jackson Scientific Computing, McKinleyville, CA 95521**

To restore the estuarine/riverine system of the Central Valley requires an understanding of how actions in different parts of the system interact, and how they compare in effectiveness. Because salmon range widely throughout the system, they may respond to restoration actions in different locations, and their response will be difficult to distinguish from variability due to natural and human factors. Population-level modeling allows comparison of potential responses to actions taken in different locations and times. We present the Sacramento River Chinook Model, a state-of-the-art individual-based model designed to investigate the consequences of various alterations in the Central Valley. The principal utility of the model is in exploring consequences of actions that alter population characteristics such as survival and abundance. For example, the model can explore the influence of flow rates in the Delta on fry production under different scenarios of survival. However, the reliability of results obtained with the model is contingent on several key inputs and possible relationships that are inadequately supported by data. Model development and testing have revealed data collection and interpretation needed to improve chinook salmon management; we challenge the research community to address these issues.

SUISUN BAY AREA MARSH CONDITIONS WITH NUMEROUS DELTA SMELT POSTLARVAE OR ADULT SPLITTAIL, CALFED TARGET SPECIES

Christopher L. Kitting*

Shore Institute and Department of Biological Sciences, California State University, Hayward, CA 94542, Phone: 510-885-3001, Fax: 510-885-4747, e-mail: ckitting@csuhayward.edu

Marshes are being restored to higher tidal action in northern San Francisco Estuary. Since January, 1999, we comparatively monitored four pairs of restored and reference marshes, which span medium to low salinity in San Pablo and Suisun bays. Our (approximately) monthly sampling with non-destructive replicate ichthyoplankton tows showed fishes generally to be rare, until March, 2000. Then, at our North San Pablo Bay Marsh, restored to higher tidal action one year earlier, this monitoring detected young splittail and numerous delta smelt postlarvae. Delta smelt was abundant in both the upper and outer shallow marsh. Our larger net sampling detected adult splittail in three deeper (about 2-m deep) marsh channels during the following month, just outside restored and reference Suisun marshes with permanent ponds, while sampling the other four channels yielded virtually no fishes. These postlarval delta smelt (about 20-mm long) populations averaged about 8 individuals/m^3, plus numerous individuals less than about 15-mm long. Our large splittail (140 to 280 mm long) averaged about 3 individuals per 500 m^3. These population densities appear be the highest reported for these species. Paired YSI 600XLM data loggers monitored water chemistry over periods greater than 24 h where the postlarval delta smelt appeared. Water conditions fluctuated with tide and daylight, similar in the upper and outer marsh, with neap tidal amplitudes about 3 ft (1 m), salinities 4 to 7 ppt (10% to 20% seawater, highest at low tide), temperatures of 12 to 17 °C (highest during daytime), and oxygen at 50% to 100% saturation (highest during afternoons). Our other sites had lower salinities and far fewer delta smelt. All sites had silt bottoms <1.5 m deep, marsh vegetation within meters, and 9~15-cm water clarity (low, as Secchi depth). Splittail adult water conditions during daytime high tides were 1.6 to 4.9 ppt salinity, 14 to 16 °C, saturated O_2, and 15 to 30 cm secchi depth. Such marsh conditions in spring may prove to favor these threatened fish populations, targeted for enhancement by CALFED habitat restorations.

NATURAL AND HUMAN INFLUENCES ON FRESHWATER FLOWS AND SALINITY IN THE SAN FRANCISCO BAY-DELTA ESTUARY AND WATERSHED

Noah Knowles

Scripps Institution of Oceanography, Climate Research Division, La Jolla, CA 92037
Phone: 858-539-2086, Fax: 858-534-8561, e-mail: noah@ucsd.edu

Understanding the processes controlling the physics, chemistry, and biology of the San Francisco Bay-Delta estuary is complicated by both natural and human effects on freshwater inflows. To investigate implications for the estuary, changes in inflows due to major reservoirs and freshwater diversions (Delta exports) in the watershed were inferred from available data. Effects on Bay-Delta salinity were estimated by using the reconstructed Delta outflows to drive a numerical salinity model. Both natural and human-induced signals show strong interannual variability. Though reservoir effects are negatively correlated with both natural variability and Delta exports overall, relative effects vary strongly within the average year. Human effects combine to raise salinities during the wet season, with maximum impacts occurring in spring. On average, May is the time when human impacts are greatest and human and natural effects are least correlated. While year-to-year variations in all signals are very large, natural interannual variability can greatly exceed the range of human effects on water quality in the estuary.

MODELING THE HYDROCLIMATOLOGY OF THE BAY-DELTA WATERSHED AND ESTUARY

Noah Knowles[*1], D. Cayan[1], K. Georgakakos[1], M. Dettinger[1], and D. Peterson[2]

[1]**Scripps Institution of Oceanography, Climate Research Division, La Jolla, CA 92037**
Phone: 858-539-2086, Fax: 858-534-8561, e-mail: noah@ucsd.edu

[2]**U.S. Geological Survey, 245 Middlefield Road, Menlo Park, CA**

A newly-developed computer model which simulates the hydrology of the about 140,000 km^2 watershed at a 4 km resolution will be presented, and simulation results pertaining to the seasonal-interdecadal variability of the watershed and estuary will be discussed. The new model is a physically-based mesoscale snow/soil moisture/river routing model, developed from available data describing the watershed's topography, landcover, soils and meteorological data. The physically-based mesoscale approach is ideally suited for studies of climate variability and its effect on the watershed/estuary system. Some preliminary results concerning the year-to-year variability in the natural partitioning of water into snowmelt, evapotranspiration, and streamflow will be presented. Simulated hydrological and estuarine effects of potential climate variability, such as a warming trend, will also be discussed.

PESTICIDES IN THE SACRAMENTO-SAN JOAQUIN DELTA: STATE OF OUR KNOWLEDGE

Kathryn M. Kuivila*

U.S. Geological Survey, Placer Hall, 6000 J Street, Sacramento, CA 95819-6129
Phone: 916-278-3054, Fax: 916-278-3071, e-mail: kkuivila@usgs.gov

Pesticides pose a potential threat to aquatic organisms in the Sacramento-San Joaquin Delta, an ecologically important habitat and a location for ecosystem restoration. It is critical to understand the effects of pesticides on the ecosystem and to be aware of possible changes in the distribution and bioavailability of pesticides as a result of proposed water conveyance and restoration projects.

The four major seasonal patterns of riverine inputs of pesticides to the Delta can be identified by usage and transport mechanism. Dormant spray insecticides applied to orchards are transported by rainfall during the winter. Alfalfa pesticides are detected following rainfall in the spring, and rice pesticides are detected following release of rice field water. Irrigation return flows transport a variety of herbicides during the summer. In addition, pesticides applied on Delta islands can cause elevated pesticide concentrations in localized areas. Studies of dissolved pesticides in the Delta show that concentrations vary considerably in time and space; therefore, effective monitoring programs should be designed to target specific questions, such as exposure of a species of interest.

More than 150 pesticides are applied annually in the Delta watershed, but only a small fraction of these are analyzed in monitoring studies. Pesticide use is also changing, with new classes of compounds, such as pyrethroids, being used more frequently. This "moving target" and lack of data about most pesticides makes it difficult to pinpoint which pesticides may cause potential problems. Future monitoring studies should include a careful evaluation of which pesticides are, or are not, being analyzed.

Sediment-associated pesticides are transported from rivers into Suisun Bay during high flows, but no data are available on their possible retention within the Delta. Consequently, the possibility of pesticide mobilization from the original sediments at a site or from sediments brought in for fill should be considered in ecosystem restoration.

CHANGES IN FLOW REGIME AND SEDIMENT BUDGET IN THE SACRAMENTO-SAN JOAQUIN RIVER SYSTEM SINCE 1850: IMPLICATIONS FOR RESTORATION PLANNING

G. Mathias Kondolf

Department of Landscape Architecture and Environmental Planning, University of California, Berkeley, CA 94720-2000, e-mail: kondolf@uclink.berkeley.edu

The flow regimes, sediment budgets, and channel dynamics of tributaries to the Sacramento and San Joaquin rivers have been altered since 1850 to a far greater extent than generally appreciated. Reservoir storage (now about 3.5 109 m^3 basin-wide) is equivalent to about 80% of mean annual runoff in the Sacramento River basin, about 135% in the San Joaquin. As a result of this reservoir regulation, winter floods have been reduced, typically by 40% to 90%, reducing sediment transport capacity and channel dynamics. Prior to 1850, the mountainous reaches of the Sacramento, San Joaquin, and tributary rivers delivered an average of about 1.3 x 106 m^3 of sand and gravel to the valley floor annually. Reservoirs now trap all but about 0.24 x 106 m^3, an 83% reduction in bedload sediment supply. The sediment deficit is exacerbated by extraction of sand and gravel for construction aggregate. Statewide, about 100 x 106 m^3 of sand and gravel is extracted from channel and floodplains annually, of which at least 20 x 106 m^3 are extracted from rivers in the Sacramento-San Joaquin system, virtually all downstream of reservoirs. The scale of the current sediment deficit dwarfs even the historical pulse of sediment from hydraulic mining. Hydraulic mining increased the annual average yield of sand and gravel to about 6.5 x 106 m^3 annually from 1860-1884, but reservoirs and gravel extraction now result in an average annual sediment deficit of over 20 x 106 m^3 annually in the Central Valley.

Understanding the scale of these transformations provides a useful context in which to evaluate restoration options. Reductions in high flows and sediment supply (along with increased riprap and levees along banks) have reduced the dynamic channel processes that create and maintain habitats. Small-scale restoration projects can be beneficial, but not necessarily sustainable in light of changes in the larger processes in the system.

LATERAL VARIABILITY IN TWO CHANNELS IN SUISUN BAY

Jessica R. Lacy[*1], S.G. Monismith[1], and J.R. Burau[2]

[1]**Environmental Fluid Mechanics Lab, Dept. Civil and Environmental Engineering, Stanford University, Stanford, CA 94305-4020, Phone: 650-723-1825, e-mail: jlacy@stanford.edu**

[2]**U.S. Geological Survey, Placer Hall, 6000 J St., Sacramento, CA 95819**

Cross-channel gradients in density and velocity can influence estuarine flows in several important ways. First, they cause lateral variability in salt and water transport, making transport difficult both to measure and to model accurately. Secondly, they produce transverse currents, which can be an important mixing mechanism. In addition, the interaction of transverse currents with lateral gradients in velocity contributes to the momentum balance governing streamwise velocities. We have studied lateral variability in current velocities, salinity, temperature, and suspended-solids concentration in Suisun Cutoff and Snag Channel (which connects Suisun Cutoff to Honker Bay). Measurements were taken in transects across each channel over a 12.5 hour tidal cycle. In both channels significant lateral structure was observed. In Snag Channel transverse circulation is caused both by curvature in the channel and lateral baroclinic forcing. In Suisun Cutoff the lateral structure is created by the confluence of flows from Grizzly Bay and from the Mothball Channel during flood tides. Curvature and junctions occur in many locations in Suisun Bay and the Delta. Our results indicate that lateral structure must be taken into account to understand and accurately model flows in this region.

TMDL DEVELOPMENT TO CONTROL DO DEPLETION IN THE SAN JOAQUIN RIVER DEEP WATER SHIP CHANNEL

G. Fred Lee and A. Jones-Lee

G. Fred Lee & Associates 27298 E. El Macero, CA 95618
Phone: 530-753-9630, Fax: 530 753-9956, e-mail: gfredlee@aol.com.

The Central Valley Regional Water Quality Control Board placed the San Joaquin River (SJR) Deep Water Ship Channel (DWSC) near Stockton on the Clean Water Act 303(d) list of impaired waterbodies based on dissolved oxygen (DO) concentrations falling below the water quality objective (WQO) for protection of aquatic life. This listing requires that wastewater dischargers and land runoff managers in the SJR DWSC watershed control the discharge of oxygen-demanding constituents through the total maximum daily load (TMDL) regulatory process so that DO WQO violations do not occur. A substantial part of the oxygen demand that leads to DO concentrations below a WQO is due to the discharge of N and P to the SJR and its tributaries that develops into algae that are transported into the DWSC where they die and exert a DO demand. There is a large surplus of N and P compared to that needed to support current algal biomass. It will be necessary to reduce N and/or P to growth rate limiting concentrations to limit algal growth that leads to DO depletion in the DWSC. The nitrification of ammonia and organic nitrogen has also been found to be an important cause of oxygen depletion within the DWSC. Upstream of DWSC diversions of SJR water leads to longer hydraulic residence times within the DWSC which aggravates the DO depletion problem. One of the most important issues in TMDL development is the TMDL DO goal. A review is presented on issues pertinent to TMDL development and implementation to control the DWSC DO depletion below the WQO.

ENVIRONMENTAL CONDITIONS AND LOWER FOOD WEB PRODUCTION IN NORTHERN SAN FRANCISCO ESTUARY, 1975–1993

Peggy W. Lehman*

Environmental Services Office, California Department of Water Resources, 3251 S Street, Sacramento, CA 95816, Phone: 916-227-7551, Fax: 916-227-7554, e-mail: plehman@water.ca.gov

Many changes in environmental and biological variables occurred in the northern San Francisco Estuary between 1975 and 1993. Streamflow and variables directly affected by streamflow, including nutrients and salinity, varied with climatic conditions that produced wet conditions in the late 1970s and early 1980s and drought conditions in the late 1980s and early 1990s. An increase in water transparency, wind velocity, water temperature and precipitation after 1980 was superimposed on this wet and dry pattern, but differed among regions and seasons. The largest cumulative change occurred upstream during the spring when water transparency, water temperature, wind velocity and precipitation simultaneously increased after 1980. These physical changes upstream were accompanied by a decrease in total organic, phytoplankton and zooplankton carbon. Significant cross correlation among these trends in environmental and biological variables calculated using time series analysis was used to develop a conceptual model of the interaction between lower food web production and natural changes in environmental conditions. Knowledge of these interactions is essential for development of successful rehabilitation plans for the estuary.

THE CONTRIBUTION OF ALGAL BIOMASS TO OXYGEN DEPLETION IN THE LOWER SAN JOAQUIN RIVER

Peggy W. Lehman* and C. Ralston

Environmental Services Office, California Department of Water Resources, 3251 S Street, Sacramento, CA 95816, Phone: 916-227-7551, Fax: 916-227-7554, e-mail: plehman@water.ca.gov

Low dissolved oxygen concentration has characterized the deep water channel in the lower San Joaquin River during the fall since the late 1960s. Here dissolved oxygen concentration is frequently below the EPA standard of 5 mg/L for aquatic health and the RWQCB standard of 6 mg/L for upstream migration of fall-run chinook salmon. Despite management, the frequency of concentrations lower than the standard during the 1990s was 1% to 27% for 5 mg/L and 11% to 49% for 6 mg/L and was only somewhat lower than the frequency in the 1970s. In 1999, longitudinal and vertical profiles indicated oxygen concentration below 5 mg/L and 6 mg/L occurred between Disappointment Slough and the Turning Basin, an 11.8 mi reach of the river. Low concentration occurred at the bottom, but was not accompanied by a strong vertical salinity or temperature gradient. The oxygen deficit from the 5 mg/L and 6 mg/L standard reached 1.5 mg/L and 2.5 mg/L respectively in the channel and was highest at the upstream boundary. Average chlorophyll *a* concentration in the channel ranged from 68 mg/m^2 in December to 170 mg/m^2 in August and was also highest at the upstream boundary. Estimated production and respiration rates suggested algal biomass contributed up to 100% of the oxygen deficit from the 5 mg/L or 6 mg/L standard at stations in the channel. Daily net transport studies suggested the oxygen demand from algal growth and respiration in the channel could exceed the demand from the load of upstream algae by a factor of 3. Future studies funded by CALFED in fall 2000 will more fully quantify the contribution of algal load compared with other sources of oxygen demand, identify controlling mechanisms and evaluate management alternatives needed to develop an adaptive management program.

A STANDARDIZED QUANTITATIVE EXTINCTION RISK ASSESSMENT OF CALIFORNIA'S ANADRAMOUS SALMONIDS

Steven T. Lindley*

National Marine Fisheries Service, 3150 Paradise Dr., Tiburon, CA 94920
Phone: 415-435-3149, ext. 217, Fax: 415 435-3675, e-mail: Steve.Lindley@noaa.gov

The National Marine Fisheries Service has completed coast-wide status reviews of Pacific salmon and anadramous trout. Due to the scope of these reviews and the limited time available, quantitative extinction risk assessments were not included. Quantitative risk assessments are still needed, however, to guide recovery efforts. The advection-diffusion model of population growth (Dennis et al. 1991, Ecol. Monogr. 61:115) is an attractive approach because all model parameters can be estimated from population time series and various extinction statistics are analytical functions of these parameters. The usual approach to parameter estimation, however, is not robust to measurement error, which can be large in many salmonid time series. This problem is solved by placing the advection-diffusion model in state-space form and estimating population growth and its variance with the Kalman filter. The method is applied to a variety of chinook, coho and steelhead population time series from throughout California. By using a standardized risk assessment method, risks can be compared across species and regions.

FISH PASSAGE SUCCESS WITH ARCHIMEDES LIFTS AND A HELICAL PUMP ON THE SACRAMENTO RIVER

Charles R. Liston[*1], C. McNabb[2], S. Borthwick[3]

[1]**Bureau of Reclamation, 168 Ralston Road, Bedford, KY 40006**
Phone: 502-255-9168, Fax: 502-255-9168, e-mail: CRList@aol.com

[2]**86 Woodland Circle, Highlands Ranch, CO 80126**

[3]**Bureau of Reclamation, NC-102, Red Bluff, CA 96080**

Water conveyance facilities under the CALFED Bay Delta Program require new technologies for fish screening. Development of low hydraulic head for bypasses at Delta fish facilities offers advancements. However, lifting water requires that fish pass unharmed. Research addressing this and coordinated with NMFS, FWS, CDWR, and CDFG, has been ongoing by Reclamation at the Red Bluff Research Pumping Plant (RBRPP), Sacramento River. Experiments using juvenile salmon (34 to 75 mm) were conducted to determine fish survivorship and injury from pump and lift passage. Twenty seven trials compared effects of two Archimedes lifts while 40 trials compared effects between Archimedes lifts and the helical pump. Treatment fish were inserted in intakes while control fish were released in discharges. Data were expressed as percentages of affected fish per trial for mortality, fish descaled, and fish with other sublethal injuries. A lift or pump effect was indicated when means for treatment samples were larger and differed significantly from means for control samples. No pump passage effect on mortality was detected in the Archimedes only experiment. Mean mortality in treatment and control samples was low: 1.2% to 1.8% respectively. In the Archimedes versus helical tests, a low pump passage effect on mortality (2.6%) was detected only for the internal helical pump. Pump passage effects were not detected in either experiment for percent fish descaled, or for percent fish with other sublethal injuries. Entrainment monitoring at RBRPP is corroborating experimental results, with high survival in 29 species sampled. We conclude that the Archimedes lifts and internal helical pump tested at Red Bluff are fish friendly, and that this technology can be considered for future CALFED water diversions and fish screen sites.

GEOMORPHOLOGICAL FUNCTIONING—MAKING THE WHOLE ESTUARY WORK FOR CALFED

Jeremy P. Lowe* and J.S.Pethick

Department of Marine Sciences and Coastal Management, University of Newcastle, Newcastle, NE1 7RU, United Kingdom, Phone: +44 191 222 5607, Fax: +44 191 222 5095, e-mail: j.p.lowe@ncl.ac.uk

One of the difficulties of implementing a managed realignment policy in estuaries is to overcome a natural tendency among coastal managers towards relatively small scale, isolated, schemes which ignore the large-scale morphodynamics of the estuary.

Since managed realignment involves the restoration of areas of the inter-tidal zone to tidal flooding, it follows that it also involves an increase in tidal prism. This can amount to a significant increase in tidal current velocity causing erosion of the channels that provides tidal water to the retreat site. In addition, the proportion of intertidal will affect the tidal asymmetry of the estuarine system as well as the demand for sediment in the context of rising sea levels.

In view of such estuarine-scale interactions, any managed realignment of a flood embankment within an estuary should be part of a large-scale design in which the total morphodynamics of the estuary are incorporated. This paper reports on research undertaken to understand the geomorphological functioning of the whole estuary and the role of individual components (mudflats, saltmarsh, sub-tidal channels etc.), to predict sustainable estuarine forms, their future evolution with rising sea levels and their modification by realignment and by dredging.

Example strategies from UK estuaries, using realignment to benefit multiple users, will be used to illustrate the potential for application to the San Francisco estuary. Recent experience in the UK with the practical implementation of realignment will also be examined, particularly concerning site design and the beneficial use of dredged material.

SPATIAL VARIABILITY OF ECOLOGICAL FUNCTION BETWEEN AND WITHIN FLOODED ISLANDS: LESSONS FOR RESTORATION AND MONITORING

Lisa V. Lucas*, J.E. Cloern, J.K. Thompson, and N.E. Monsen

U.S. Geological Survey, 345 Middlefield Road, MS 496, Menlo Park, CA 94025
Phone: 650-329-4588, Fax: 650-329-4327, e-mail: llucas@usgs.gov

Flooded islands represent a subset of "shallow water habitats," which have been proposed as a means of recapturing certain of the Delta's living resources and ecological functions. Flooding of more islands may also be implemented to increase water storage in the Delta. We conducted a field study to answer these questions: How do flooded islands function ecologically, and do ecological characteristics vary between or within them? What modes of spatial and temporal variability must we consider when monitoring these habitats? As part of a larger integrated project concerned with food availability to zooplankton in the Delta, this study focused on the phytoplankton biomass available to the pelagic foodweb in flooded islands. This study involved high-resolution spatial mapping of water quality constituents (including phytoplankton biomass) and of benthic filter feeders in two flooded islands: Franks Tract (FT) and Mildred Island (MI). Passive drifters were simultaneously tracked for understanding water transport during the study. We learned an important lesson for restoration: although superficially similar, FT and MI function very differently with respect to phytoplankton biomass available to the pelagic foodweb—one is apparently a net source, and the other a net sink. Furthermore, a flooded island may itself contain a range of ecological conditions. These spatial differences between and within flooded islands depend on tidally driven transport, depth, and benthic grazers. We also identified important lessons for monitoring of these habitats. First, spatial variability of water quality and ecological function within a flooded island may require multiple sampling locations. Second, spatial patterns vary significantly over hourly timescales due to tidal transports; therefore, consideration of tidal phase is necessary when sampling. Third, the degree of spatial heterogeneity may vary over weekly timescales due to modulated mixing over the spring-neap cycle; therefore, higher-resolution spatial sampling may be required on neap tide than on spring tide.

TIDAL REGIMES AND NON-TIDAL VARIATIONS IN WATER LEVEL IN THE SAN FRANCISCO ESTUARY

Karl P. Malamud-Roam*

Contra Costa Mosquito and Vector Control District, 155 Mason Circle, Concord, CA 94520
Phone: 925-685-9301 ext. 107, Fax: 925-685-0266, e-mail: kmalamudroam@ccmvcd.net

The interactions of tidal and non-tidal influences on water level are critical to the hydrodynamics of the San Francisco Estuary, as well as to processes in the tidal marshes and other shallow water areas along the estuary's margins. In this study, I conducted statistical analyses of water level records for the estuary dating back to 1854, in order to better characterize variations in water level in the estuary on a range of spatial and temporal scales. In particular, I evaluated water level regimes in relation to (1) daily, seasonal, extreme, and long-term tidal patterns at the Golden Gate; (2) tidal wave propagation through the estuary; and (3) non-tidal influences on tidal patterns and on water level. Results of these analyses include a redefinition of the "mixed semi-diurnal" tidal regime, recognizing a previously undescribed strong tropical fortnight (13.66 day) cycle; a 320 year cycle of seasonal patterns of diurnal high and low water timing, with substantial importance for shallow-water ecology; variable seasonality of different tidal means (HW, MSL, LW, etc.); an increasing tidal range and therefore greater potential for flooding due to rising sea level than is generally recognized; a new classification of tidal residuals (i.e. non-tidal variations in stage due to ENSO, runoff, barometric pressure, etc.) by mechanism and therefore by persistence; and new algorithms for forecasting water levels that integrate tidal and non-tidal influences, with a 60% reduction in forecast error for short- to medium-term forecasts.

THE AB 360 PROGRAM: A PROGRAM OF SYNERGY BETWEEN HABITAT CREATION AND LEVEE MAINTENANCE IN THE DELTA

James L. Martin* and C. Schmutte

California Department of Water Resources, 3251 S Street, Sacramento, CA 95816
Phone: 916-227-7581, Fax: 916-227-7600, e-mail: jimm@water.ca.gov

Synergy is the driving force behind the AB 360 Program. The AB 360 Delta Levee Protection Program, administered by the California Department of Water Resources' (DWR) Central District, has the dual mission of creating diverse habitats in the Delta, while providing protection of the Delta levee system.

DWR is currently managing many successful AB 360 levee habitat mitigation and enhancement projects in cooperation with several federal, State, and local agencies. Projects include creation and restoration of habitat types including shaded riverine, scrub-shrub, emergent marsh, shallow water, and riparian forest habitat.

AB360 funds are being used for habitat in the Delta and a portion of eastern Suisun Marsh. In the DWR/US Army Corps of Engineers Lower Sacramento River Revegetation Study, approximately 1,000 lineal feet of riparian, grassland, and tule marsh habitat is being developed along Steamboat Slough on Grand Island.

Another significant effort is the restoration of 35 acres of diverse wetland and riparian habitat on the DWR's 490 acre Grizzly Slough Property. Approximately 70,000 cubic yards of material was removed for levee maintenance and to make topographic changes in the landscape, creating open water areas, sloughs, berms, and upland areas. These areas were subsequently planted with selected vegetation for development of oak woodlands, riparian, and wetland habitats.

Other current activities include habitat being developed on 2,000 lineal feet of rip rapped levee on Tyler Island through the installation of prefabricated containerized plants in the rip rap and on a berm on the waterside of the levee.

The AB 360 Program is continuing to make substantial progress through its levee maintenance and habitat development activities. This synergy between projects helps to reduce costs while making significant strides to meet the legislative mandate for habitat enhancement.

GREEN STURGEON BIOENERGETICS: TEMPERATURE EFFECTS

Ryan B. Mayfield* and J.J. Cech, Jr.

Dept. of Wildlife, Fish, and Conservation Biology, 1 Shields Ave., University of California, Davis, CA 95616, Phone: 530-752-8659, e-mail: rbmayfield@ucdavis.edu

Green sturgeon (*Acipenser medirostris*) are rare in the Sacramento-San Joaquin Estuary, compared with congeneric white sturgeon (*Acipenser transmontanus*), and we know little about them. However, basic life history information is critical to this species' protection. We addressed this need by measuring temperature and ration size effects on age-0 green sturgeons' food consumption, growth, and food conversion rates at 11, 15, and 19 °C. We also measured temperature effects (11, 19, and 24 °C) on the routine metabolic rate and thermal preferences on age-0 green sturgeon and resting routine metabolic rate and swimming performance of age-1 green sturgeon. Increases in temperature and ration size generally increased green sturgeon food consumption rates (to maxima at 19°C) and growth rates (19 °C values not statistically distinguishable from those at 15°C) at both ration levels (50% and 100% of satiation). Routine and resting routine metabolic rates increased at the highest temperatures, only. Volitional activity (tail beats) in routine metabolism experiment fish increased with increases in temperature over the entire 11 to 24 °C range. Green sturgeon acclimated to 24 °C preferred a significantly higher temperature (20.4 °C) than those acclimated to either 11 or 19 °C, which were statistically indistinguishable (15.3 °C and 15.2 °C, respectively). Thus, although food consumption rate benefits from warming temperature over the 11 to 19 °C range, growth rate does not increase as the water warms above 15 °C (the preferred temperature of the 11 and 19 °C fish), possibly due to the energetic demands associated with the increasing volitional activity at warmer temperatures. These temperature and ration-related responses should assist managers in preserving green sturgeon in the Sacramento-San Joaquin Estuary. Research supported by CALFED Bay-Delta Program.

CENTRAL VALLEY STEELHEAD: BIOLOGY, MANAGEMENT, AND "NEW" CONCEPTS FOR RECOVERY

Dennis R. McEwan*

Native Anadromous Fish and Watershed Branch, California Department of Fish and Game, 1807 13th St., Suite 104, Sacramento, CA 95814, Phone: 916-327-8850, Fax: 916-327-8854, e-mail: dmcewan@dfg.ca.gov

Steelhead were broadly distributed throughout the Central Valley drainages prior to extensive water development. Today, most of their former range is inaccessible due to the construction of impassable barriers but natural stocks currently persist in both the Sacramento and San Joaquin river systems. Historical run size was probably at least one to two million adults annually but by the early 1960s had declined to about 40,000 adults and is substantially less than that today. The primary stressor affecting Central Valley steelhead is the loss of spawning and rearing habitat due to dams and other artificial barriers. There is evidence that native Central Valley steelhead have maintained some degree of genetic integrity despite the introduction of exotic stocks. Ecological theory and evidence from genetic and otolith microchemistry analyses suggest that Central Valley rainbow trout populations are polymorphic, that is, all life- history forms (e.g., resident and anadromous) in a given stream system comprise a single population and progeny can assume a life-history strategy different from that of their parents. Central Valley anadromous fish management and research are primarily focused on chinook salmon and this has lead to inadequate efforts to monitor and restore steelhead. Steelhead recovery and management strategies are governed by the old paradigm that steelhead form discrete populations and are similar to chinook salmon in life-history. This has led to ineffectual management strategies as evidenced by their listing under the Endangered Species Act. The old paradigm needs to be replaced by a new one whereby steelhead recovery strategies are guided by population ecology concepts such as within- and between- population dynamics and persistence in marginal, highly variable environments. Strategies that will provide the greatest recovery benefit are those that focus on restoring access to historical habitat where the resiliency inherent in a diverse population structure can be fully expressed.

SEASONAL FEEDING HABITS OF STEELHEAD TROUT IN THE LOWER MOKELUMNE RIVER, CALIFORNIA

Joseph E. Merz*

East Bay Municipal Utility District, 1 Winemasters Way, Suite K, Lodi, CA 95240
Phone: 209-365-1093, Fax: 209-334-3795, e-mail: jmerz@ebmud.com

I examined the stomachs of 179 steelhead trout, *Oncorhynchus mykiss*, sampled seasonally from the lower Mokelumne River, January 1998 through December 1999. Post-yearling (1+) steelhead trout (STH) fed primarily on hydropsychid larvae, chironomid pupae, zooplankton (primarily daphniids) and baetids (subimago and nymphs). Although the trout supplemented their diets with small terrestrial mammals, crayfish, and several species of fish (20 mm TL), the mean prey item size ingested by STH was less than 2.5 mm. This did not change relative to the FL of STH in either year. STH occasionally ingested benthic organisms dislodged from feeding and spawning activities of other salmonids. Small mats of filamentous algae were also consumed throughout the year, presumably for the zooplankton and early instar insects entrained in the material. Overall, steelhead trout fed less during the 1999 season than the previous year and this may be attributed to cooler water temperatures.

SPAWNING HABITAT RESTORATION IN THE STANISLAUS RIVER

Carl Mesick*

Carl Mesick Consultants, 7981 Crystal Boulevard, El Dorado, CA 95623
Phone: 530-620-3631, Fax: 530-620-3631, e-mail: cmcfish@innercite.com

To improve the methods of restoring spawning habitat for fall-run chinook salmon, CALFED funded a demonstration project on the Stanislaus River. Spawning habitat in the Stanislaus River has been degraded by in-river gravel mining and dams, but few spawners used restoration gravel added in 1994.

An objective of this project was to test whether the source and size of gravel, riffle location, and streambed configuration affect spawner use. The sources of restoration gravel were quarries on the Stanislaus and Tuolumne rivers. All of the Tuolumne River rock and half of the Stanislaus Rock were processed with a 3/8-inch screen and a five-inch grizzly. The remainder of the Stanislaus River rock was similarly processed except that a 1/4-inch screen was used. The rock was placed at 18 sites located 2 to 18 miles below Goodwin Dam. Restoration sites were segregated into high, moderate, and low crested riffles. Gravel was placed at all sites to create a high crest similar to the tail of a pool. Seven riffles were monitored as controls.

Prior to gravel placement, redd densities at the project sites were typically lower than those at the control sites; whereas after gravel placement, redd densities increased at 15 sites. In 1999, there was a negative correlation between redd densities and the distance downstream from Goodwin Dam. Based on the slope of these regressions for each gravel type, the average redd density was 1.8 times higher at the riffles with 1/4-inch-plus Stanislaus River rock than at control riffles and 1.3 times higher at the riffles with 3/8-inch-plus Stanislaus River rock than at control riffles. However, redd densities at the riffles with Tuolumne River rock were 0.6 times the densities at the control sites. There were no correlations between redd density and the height of the natural streambed crest.

ESTIMATING POPULATION LEVEL EFFECTS ON FISH FOR ENVIRONMENTAL REQUIREMENTS AFFECTING DELTA WATER PROJECT OPERATIONS

William J. Miller*

Consulting Engineer, P.O. Box 5995, Berkeley, CA 94705
Phone: 510-644-1811, Fax: 510-644-8278, e-mail: bjmill@aol.com

State and federal water project operations in the Sacramento-San Joaquin Delta are constrained by regulatory requirements set to protect fish. Requirements have been imposed to increase fish populations. Estimates of population level effects have not generally been made. This paper presents such estimates for salmon and for estuarine species whose abundance correlates with X2 (Delta outflow).

Data collected over the last 15 to 25 years demonstrate relationships between population levels and regulatory requirements. The validity of relationships between regulatory requirements and fish populations or survival is a matter of dispute. In this paper I set that dispute aside. I used the relationships to determine how changes in population were associated with requirement-induced changes in water project operations.

I assumed that, for any year class of salmon, the population of adult salmon is proportional to the number of salmon smolts successfully migrating through the Delta. That is, there is no “density dependence” in or downstream of the Delta. If there were, the estimated amounts of water would be greater.

Note that the estimated amounts of water do not necessarily equate to a water supply loss. Sometimes, all or part of the water supply loss can be made up. Therefore, the water amounts should be regarded as estimates of the risk of water supply losses.

Results indicate that amounts of water associated with a one-percent increase in fish population ranged from 50,000 acre-feet to 1,800,000 acre-feet, depending on the species, requirement, and the method of estimation. Amounts of water were generally proportional to the percent increase and, in some cases, to the river flow or Delta outflow from which the change is made.

FISH ENTRAINMENT MONITORING FOR THE OLD RIVER PUMPING STATION USING AN "ON-STREAM" SCREEN

Jerry Morinaka*

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: jmorinak@delta.dfg.ca.gov

The Old River Pumping Station is a new screened facility in the south Delta using an "on-stream" oriented positive barrier fish screen design. We monitored fish entrainment at the Old River Pumping Station from March 1998 through June 2000 to evaluate the effectiveness of the screened intake facility. The most abundant larval fish species captured behind the fish screens were prickly sculpin, threadfin shad, and white catfish, and occurred during the months of June through August. Although the nearby State and Federal fish salvage facilities have taken high numbers of delta smelt, results of the monitoring program have indicated that entrainment of delta smelt at the pumping station appears to be minimal.

FOOD QUANTITY AND QUALITY FOR *DAPHNIA* IN THE SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

Anke B. Mueller-Solger*, K. Forshay, and D. Mueller-Navarra

Dept. of Environmental Science and Policy, University of California, 1 Shields Ave., Davis, CA 95616
Phone: 530-752-2913, Fax: 530-752-3350, e-mail: abmuellersolger@ucdavis.edu

In this study we have investigated nutritional factors limiting zooplankton growth in various habitats of the Sacramento-San Joaquin Delta by measuring *Daphnia magna* growth and egg production rates when fed seston collected from various Delta habitats during different seasons. Four-day feeding assays were conducted in the laboratory with *Daphnia* neonates grown at 20 °C using a flow-through system and including unialgal control treatments. We measured seston carbon, nitrogen, phosphorus, chlorophyll and fatty acid contents as well as carbon and nitrogen stable isotope signatures. Several of these variables were significantly related to *Daphnia* growth rates and may thus serve as indicators of nutritional habitat quality for zooplankton. *Daphnia* growth rates were most strongly related to chlorophyll concentrations, indicating the nutritional importance of phytoplankton over detrital matter for secondary production in this detritus-rich system. Also, we found large nutritional differences between habitats and seasons, with highest rates of *Daphnia* growth and egg production when fed seston from shallow habitats with long residence times (tidal marsh, flood plains, and a flooded island site) compared to deeper habitats (large tidal rivers).

THE POTENTIAL FOR SUBSIDENCE CONTROL THROUGH WETLANDS RESTORATION IN THE SACRAMENTO-SAN JOAQUIN DELTA

Robin L. Miller* and R. Fujii

U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA 95819
Phone: 916-278-3062, Fax: 916-278-3071, e-mail: romiller@usgs.gov

Soil subsidence is an increasing concern in the Sacramento-San Joaquin Delta, where land-surface elevations are as much as 25 feet below sea level. Levee maintenance and repair costs, and the risk of levee failure, grow with the increase in hydraulic gradient between channel and land. This subsidence primarily results from the decomposition of mechanically drained organic soils. The peat soils of the Delta formed under vast tule and reed marshes that flourished for several thousand years prior to their drainage and conversion to agriculture in the late 19th and early 20th centuries. In an effort to reestablish wetland conditions, which can be conducive to carbon storage, and thereby may mitigate subsidence, organic soils on Twitchell Island were shallowly flooded in 1997 to two different depths of approximately one and two feet each.

The carbon storage potential of the resulting marshes can be evaluated by comparing estimates of carbon inputs to losses of carbon from the system. Estimates of net primary production were made using destructive biomass harvests of above- and below-ground material coupled with measured rates of standing biomass turnover for the dominant emergent macrophytes, *Typha* (cattails) and *Scirpus acutus* (tules). These estimates show that the marshes are highly productive systems, with some areas generating upwards of 3 kilograms of carbon per square meter per year. Carbon losses were assessed through estimates of gaseous carbon losses and litter decomposition studies. Gaseous carbon losses dropped dramatically upon conversion from a drained agricultural field to wetlands, but increased steadily as wetland plants colonized the flooded soils. Measured gaseous carbon losses were dramatically lower than estimated carbon inputs, indicating that these wetlands have tremendous carbon storage potential.

TRANSPORT MECHANISMS FOR WATER AND SCALARS IN THE DELTA

Nancy E. Monsen* and S.G. Monismith

Environmental Fluid Mechanics Laboratory, Department of Civil and Environmental Engineering, Stanford University, Stanford, CA 94305-4020, Phone: 650-723-1825, Fax: 650-725-9720, e-mail: winter@leland.stanford.edu

When water is released from the reservoirs upstream of the Delta to fulfill the export requirements at the South Delta pumps, the volume needed for pumping is released plus an additional amount, termed carriage water. This additional water is sent down the system to prevent salinity intrusion into the Delta caused by pump operations. The concept of carriage water is based on the assumption that mean advective flux rather than tidal dispersive flux controls scalar transport in the Delta.

Using Delta TRIM3D, a multi-dimensional hydrodynamic and scalar transport model developed by Casulli and Cattani (1994) and Gross (1999), and modified by Monsen (2000) for Delta applications, we present results from three numerical modeling simulations (April 1997, September 1998, and November 1999). We will present a discussion of how well Delta TRIM3D represents tidally-averaged stage and flow values. Then we will use simulation results to demonstrate the main transport mechanisms for both water transport and scalar transport.

These simulations demonstrate that mean flows control water transport but mean advective flux does not control scalar transport in the entire Delta. Depending on the location of the station and the amount of inflow to the system, dispersive flux or mean advective flux can be the primary scalar transport mechanism. Two critical locations where dispersive flux controls scalar transport are Threemile Slough and Chipps Island.

One of the key results to be presented is the November 1999 simulation for the main stem of the Delta including Threemile Slough. In this low flow case during a critical salt intrusion event, the carriage water concept does not work because dispersive flux dominated transport in all the western Delta stations.

IMPACT OF TEMPORARY BARRIERS AND THE YOLO BYPASS ON TRANSPORT OF ORGANIC CARBON THROUGH THE DELTA

Nancy E. Monsen* and S.G. Monismith

Environmental Fluid Mechanics Laboratory, Department of Civil and Environmental Engineering, Stanford University, Stanford, CA 94305-4020, Phone: 650-723-1825, Fax: 650-725-9720, e-mail: winter@leland.stanford.edu

Jassby and Cloern (2000) have shown that tributary loading of bulk organic carbon is an important source of organic carbon in almost all seasons and water year types. In order to assess the food quality in different regions of the Delta, it is important to identify the tributary sources of water at any given location in the Delta.

We present results from two numerical modeling simulations using Delta TRIM3D, a multi-dimensional hydrodynamic and scalar transport model developed by Casulli and Cattani (1994) and Gross (1999), and modified by Monsen (2000) for Delta applications. We used Delta TRIM3D to predict the source fractions from the Sacramento, San Joaquin, Yolo Bypass, and agricultural return waters at any location in the Delta and Suisun Bay given the hydrology, pump operations and temporary barrier configuration.

A multi-dimensional numerical modeling approach is necessary to understand the transport mechanisms that impact food availability in this complex region. The location of temporary barriers, gate operations, and flow through the Yolo Bypass all affect Delta circulation patterns as well as the fractions of water at given points in the Delta that are derived from different possible sources like the Sacramento or San Joaquin rivers. Specific mixing characteristics in the Delta have been identified through this study. We find in particular that temporary barriers installed in the Delta can have an extremely large effect on circulation and source fractions. Consequently, while these temporary barriers may be beneficial to migrating fish, they may degrade water quality. Secondly, study of the February 1999 period shows that Yolo Bypass water flows primarily through the Sacramento ship channel into Honker Bay and Suisun Bay. This indicates that the phytoplankton produced in Yolo Bypass water is not a source of food in the Central Delta because Yolo Bypass water does not reach the central Delta.

TO BREACH OR NOT TO BREACH: LEVEE MODIFICATIONS TO SUPPORT FLOODPLAIN RESTORATION

Jeffrey F. Mount[*] and J.L. Florsheim

Dept. of Geology and Center for Integrated Watershed Science and Management, University of California, Davis, 1 Shields Ave., Davis, CA 95616, Phone: 530-752-7092, Fax: 530-752-0951, e-mail: mount@geology.ucdavis.edu

Agencies and foundations within the Central Valley are evaluating non-standard methods for reducing flood damages and enhancing floodplain and riparian ecosystems. Many of these methods involve lowering flood stage by increasing connectivity between channels and ancestral or engineered floodplains. The potential habitat and water quality benefits of these changes are considerable, but as yet unproven due to the limited number of completed projects. Levee breach experiments conducted by The Nature Conservancy on the lower Cosumnes River, coupled with examples from rivers outside California demonstrate that breaches are an effective approach to improving floodplain habitat for a range of terrestrial and aquatic species. Depending upon restoration objectives, site selection for levee breaches will be constrained by geomorphic, hydrologic, and hydraulic conditions. The optimal design for levee breaches enhances turbulent diffusion and convective transport of sediment onto and across the floodplain in order to construct crevasse splays. This is achieved by siting levee breaches within the downstream end of the outside bank of meander bends where maximum turbulence, superelevation, and secondary circulation enhance the transport of sand onto the floodplain. The location, frequency and design of breaches should minimize the difference in elevation between the floodplain and the channel thalweg, while maximizing the difference in elevation between stage and floodplain elevation. Successful levee breaches require high bedload transport rates coupled with flood pulses of sufficient magnitude, duration and frequency to support the establishment and occasional disturbance of floodplain plant communities. Additionally, multiple levee breaches should be sited to support sustained floodplain inundation during and following passage of a flood wave, and should maintaining maximum connectivity between the channel and floodplain waterbodies. The design and location of breaches that are solely for flood damage reduction projects are likely to be significantly different from breaches for restoration.

IMPORTANCE OF COSUMNES RIVER FLOODPLAIN TO CHINOOK SALMON AND SACRAMENTO SPLITTAIL

Peter B. Moyle*, P.K. Crain, and K. Whitener

Wildlife, Fish and Conservation Biology, University of California, 1 Shields Ave., Davis, CA 95616
Phone: 530-752-6355, e-mail: pbmoyle@ucdavis.edu

We sampled fishes weekly on the floodplain of the Cosumnes River, Sacramento County, January to May, 1998, 1999, and 2000. Species of particular concern were juvenile chinook salmon and Sacramento splittail. Salmon appeared on the floodplain almost as soon as it flooded and became widely distributed, although they were mostly associated with areas of flowing water. By feeding on abundant zooplankton and insects, they acheived high growth rates. As floodwaters receded, salmon left, with minimal stranding. Splittail were observed in March and April 1998 and 2000 only. In both years, spawning took place on the flood plain and large number of larvae and juveniles were produced, most of which successfully emigrated into the river as floods receded. Our results are very similar to those of those of the DWR study on the Yolo By-pass headed by T. Sommer. They suggest that both chinook salmon and splittail are highly adapted for use of floodplain habitats.

USE OF THE COSUMNES RIVER FLOOD PLAIN BY NATIVE AND ALIEN FISHES

Peter B. Moyle*, K. Whitener, P.K. Crain

Wildlife, Fish and Conservation Biology, University of California, 1 Shields Ave., Davis, CA 95616
Phone: 530-752-6355, e-mail: pbmoyle@ucdavis.edu

Creation of shallow water habitat, both seasonal and permanent, is regarded as important for restoration of native fishes. The flood plain of the Cosumnes River contains a mixture of both types of habitat and its use by fishes was studied 1998-2000. Permanent habitats (sloughs, ditches, river channel) are largely dominated by resident alien species (e.g., redear sunfish, largemouth bass, golden shiner, inland silverside) while flooded habitat is used by both natives and aliens but seems particularly important for native species. Year to year variability in use of seasonal habitat was high, by at least 22 species. Native species using it for spawning included Sacramento splittail, blackfish, and hitch and for juvenile rearing included chinook salmon, Sacramento sucker, and pikeminnow. Alien species spawning in flooded areas were mainly common carp, goldfish, and golden shiner although their use depends on water being present in late April and May. Most alien species used flooded habitats mainly for foraging and were rarely found far from source sloughs. Our data suggests that most native fishes that use flooded habitats either move down from upstream areas or migrate up from the Delta.

TWITCHELL ISLAND LEVEE SETBACK AND HABITAT RESTORATION PROJECT

Christopher H. Neudeck[*1], C.C. Schmutte[2], and E. Littrell[3]

[1]**Kjeldsen, Sinnock, & Neudeck, Inc., P.O. Box 844, 711 N. Pershing Ave., Stockton, CA 95201-0844 Phone: 209-946-0268, Fax: 209-946-0296, e-mail: cneudeck@ksninc.com**

[2]**California Department of Water Resources, 3251 S Street, Sacramento, CA 95816**

[3]**California Department of Fish and Game, 1701 Nimbus Road, Suite A, Rancho Cordova, CA 95670**

In 1989 Twitchell Island Reclamation District 1601 began construction of a landside berm to strengthen 3,000 lineal feet of levee adjacent to the San Joaquin River. This particular section of levee was unstable and engineering analysis showed that the estimated critical failure surface ran through the entire levee section. The solution was construction of a setback levee to avoid the critical failure surface. The first step was construction of a landside berm, which provided a widened base needed for the setback levee as well as a stabilizing mass (counterweight) for the existing levee. The landside berm consolidated and somewhat strengthened the underlying deep peats in the foundation of the levee.

The District began constructing the actual setback levee in 1994, taking much care during construction to avoid overstressing the underlying soils and to avoid failing the levee as the result of placing the fill too fast. The engineering criteria for the rates and conditions under which the fill was placed were successful.

The District's next step included degrading the portion of the existing levee sitting waterward of the new setback levee, along with placing quarry stone riprap on it for wave wash protection. Degrading the remnant portion of the existing levee improved the stability of the new setback levee by removing some of the driving forces associated with the critical failure surface.

Instead of simply degrading the remnant levee, the District decided to work with the California Department of Water Resources and Department of Fish and Game to create valuable habitat in the same area. In 1999 they began excavating and re-contouring the remnant levee. The grading created emergent tidal marsh and shaded riverine aquatic habitat together with achieving the District's goal to unweight the waterside slope of the levee and enhance the structural integrity of the new setback levee.

MUTUALISTIC INTERACTION BETWEEN TALORCHESTIA TRASKIANA AND SALICORNIA VIRGINICA IN A SAN FRANCISCO BAY MARSH

Steven Obrebski*, G.H. Irwin, and J. Mazzotta

Romberg Tiburon Center, San Francisco State University, P.O. Box 855, 3152 Paradise Dr., Tiburon, CA 94920, Phone: 415-338-3537, Fax: 415-435-7120, e-mail: steobre@sfsu.edu

Experimental field studies of the impact of the amphipod *Talorchestia traskiana* on production of pickleweed, *Salicornia virginica*, suggest a mutualistic relationship. The plant provides cover and a high humidity environment for large populations of amphipods. Amphipod abundance was monitored and manipulated in 1 square meter enclosures or open areas in the pickleweed zone of Muzzi Marsh in Corte Madera in Central San Francisco Bay between April and July in 1996 and 1997, during the pickleweed growth season. Pickleweed production was determined from wet or dry weight biomass per enclosure or open area. In 1996, relative to enclosures where amphipod abundance was unmodified, pickleweed production was significantly lower in enclosures where amphipod abundance was depleted and higher in enclosures where amphipod abundance was increased. In 1997, increases in amphipod abundance significantly increased pickleweed production and flowering rate. Pickleweed production increased asymptotically, and the logarithm of the number of flowers per enclosure increased linearly with cumulative amphipod abundance. As in other marshes, nitrogen limited growth. Fertilization experiments in 1999 showed that pickleweed production could be significantly increased by 44% with addition of urea nitrogen between May and August. Amphipods in enclosures burrowed in the substrate among pickleweed roots during neap tides. In open areas, amphipods were most abundant near the “wrack zone” deposited by the previous highest high tide. Pickleweed production increases can be attributed to release of nitrogen by amphipods during feeding and burrowing activities. Ongoing studies (spring and summer 2000) on the influence of amphipod abundance and migration, tidal elevation, distance from marsh channels and nitrogen distribution on pickleweed production will be summarized. This study describes a new functional relationship between an animal and plant in the pickleweed zone of North Pacific marshes and implications of this finding for marsh restoration will be discussed.

EPISODIC TOXICITY IN THE SAN FRANCISCO ESTUARY

R. Scott Ogle[*1], A. Gunther[2], J.S. Cotsifas[1], J. Gold[2], P. Salop[2], D. Bell[2], S. Hansen[3], R. Hoenicke[4], and B. Thompson[4]

[1]**Pacific EcoRisk, 835 Arnold Dr., Suite 104, Martinez, CA 94553**
Phone: 925-313-8080, Fax: 925-313-8089, e-mail: scottogle@pacificecorisk.com

[2]**Applied Marine Sciences, 4749 Bennet Dr., Suite L, Livermore, CA 94550**

[3]**S.R. Hansen & Associates, P.O. Box 539, Occidental, CA 95465**

[4]**San Francisco Estuary Institute, 1325 S. 46th St., Richmond, CA 94804**

Toxicity testing of ambient waters conducted by the Regional Monitoring Program in San Francisco Bay has indicated that, in general, there does not appear to be any consistent, wide-spread toxicity problems within the Bay's waters. A major exception to this have been the occurrences of significant toxicity in ambient water samples collected from just upstream of the confluence of the Sacramento and San Joaquin Rivers down to the mouth of the Napa River following major storm events in January and February of 1996 and 1997. It is believed that this toxicity was the result of pesticides in stormwater runoff from within the Sacramento and San Joaquin River watersheds. This suggests that significant ambient water toxicity is present in San Francisco Bay, occurring as "events" of short duration and/or of localized nature, probably the result of stormwater runoff and/or other surface water runoff events. To investigate this further, we have been collecting and performing toxicity tests on ambient water samples at selected sites in San Francisco Bay following significant rainstorm events for the past four winter seasons. The results of these tests indicate that ambient water toxicity is present in parts of the Bay immediately following runoff events. Results of ELISA analyses suggest that some of this toxicity may be due to organophosphate pesticides, while the possible causes of other toxic water samples still remains unknown.

CHANGES IN MYSID AND ZOOPLANKTON SPECIES COMPOSITION AND ABUNDANCE IN THE UPPER SAN FRANCISCO ESTUARY

James J. Orsi* and L.W. Mecum

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: jorsi@delta.dfg.ca.gov

In the last quarter-century the zooplankton fauna in Suisun Bay and the Sacramento-San Joaquin Delta has changed radically due to phytoplankton reductions and the introductions of exotic species. Since 1978, eight exotic copepods and three mysids have appeared. Two of the exotic copepods have since disappeared and two have become very abundant. One mysid has become abundant in the upper estuary and another is abundant in San Francisco and San Pablo bays. All of the once common copepods in the upper estuary have experienced severe reductions in abundance. Other zooplankton groups - cladocerans and rotifers - have also declined. Native copepods are now most abundant in spring while exotics dominate in summer and fall. Exotic species now compose 90% of the copepod population in summer and fall. Food limitation has been identified as the factor affecting the decline in the native mysid shrimp, Neomysis mercedis, and the inability of the introduced mysid, *Acanthomysis bowmani*, to reach the abundance that N. mercedis formerly had. Food limitation has also been demonstrated for Daphnia in laboratory experiments using Delta water. The summer-fall disappearance of Eurytemora, a copepod important to small fish, has been attributed to predation from the Asian clam, Potamocorbula amurensis. This clam now controls copepods and mysids in the Low Salinity Zone (LSZ) by its reduction of the phytoplankton food resource and by its predation on Eurytemora and Acartia nauplii. Copepods have also shifted from filter-feeding calanoids to grasping cyclopoids. The Chinese cyclopoid, *Limnoithona tetraspina*, is the most abundant copepod in the LSZ and frequently in freshwater also, reaching densities of 100,000/m3, greater than the abundance of any other copepod past or present. Its dominance indicates that its young escape Asian clam predation and that it uses food resources, such as nauplii, not readily available to other copepods.

APPLICATION OF A 2-D HYDRAULIC MODEL TO REACH-SCALE SPAWNING GRAVEL REHABILITATION

Gregory B. Pasternack*, C.L. Wang, and J. Merz

Land, Air and Water Resources—Hydrology, University of California, 1 Shields Ave., Davis, CA 95616
Phone: 530-754-9243, e-mail: gpast@ucdavis.edu

In-channel features such as woody debris, hydraulic jumps, and gravel bars are ubiquitous in natural rivers. An increasing body of research has detailed their geomorphic and ecologic importance for aquatic habitat. Existing rehabilitation practice minimizes or even ignores the impact of these features and instead focuses on channel geometry via stream classification. Few objective criteria exist for designing in-channel features. In this study we tested the applicability of a 2-D hydraulic model for use in gravel placement to restore salmon spawning habitat and natural fluvial complexity.

Mokelumne River is a major stream of California's Central Valley whose salmonid production is limited by low spawning habitat quality and quantity. Habitats are degraded by minimal gravel recruitment due to river impoundment and historic gravel extraction. In Fall 1999, 3200 cubic yards of gravel, woody debris and boulders were used to create bars and chutes in a 90 m reach below Camanche Dam.

A 2-D hydraulic model was used to simulate sub- and super-critical flows within the project reach. Three discharges ranging from 300 to 1100 cfs were modeled for pre- and post-project conditions. Model runs were calibrated to match observed water surface elevations, discharges, bed roughness and eddy viscosities. Post-project runs were validated with observed depth and velocity profiles.

After the project, water surface slope and velocities increased, while depths decreased. The gravel replenishment dramatically increased the coefficient of variation of depth and enhanced that of velocity. Such changes mark an important step in habitat rehabilitation. Low flow runs produced model features that match observed dry banks, islands, and boulders. Using Shields' criteria and the log-velocity profile, sediment entrainment was assessed and found to be negligible. Overall, the 2-D model is a useful tool for assessing, and ultimately designing, rehabilitation projects when used in conjunction with existing geomorphic methods.

DELINEATION OF MIXING AND FLOW DISTRIBUTION IN THE DELTA USING TRACERS AND NUMERICAL MODELING

Susan C. Paulsen and E.J. List

Flow Science Incorporated, 723 E. Green Street, Pasadena, CA 91101
Phone: 626-304-1134, Fax: 626-304-9427, email: spaulsen@flowscience.com

The distribution of waters from three major sources (the Sacramento River, the San Joaquin River, and San Francisco Bay) in the Delta, a highly complex estuarine environment, has been successfully described via two independent methods. One method utilized the measured concentrations of naturally-occurring elemental "tracers" to estimate the distribution of water from the major sources of water within the system. The second method used numerical modeling (the Fischer Delta Model, or FDM) to describe the hydrodynamics of the system and the relative proportions of source water throughout the system.

Findings include the delineation of the source of water at two interior Delta locations (Bethel Island and Clifton Court Forebay). Results indicate that the San Joaquin River is a significant source of salinity in the Delta, especially at Clifton Court Forebay. Results also show that artificial flow barriers and diversions have a major impact on the distribution and quality of water in the Delta. For example, opening the Delta Cross Channel significantly increases the amount of lower salinity Sacramento River water that reaches the south Delta. The installation and removal of barriers in the south Delta strongly impacts the flow patterns and distribution of San Joaquin River water in the south Delta. During the major flood of January 1997, concentrations of major ions indicated that an additional source of water inside the Delta must be important (e.g., agricultural drainage, which generally has higher salinity levels than river water).

These are the first results that objectively and consistently describe the distribution of waters from various sources in such a complex natural environment, and this work has significant implications for the modeling and management of water supply, water quality, and ecological resources in the Delta.

FLOODPLAIN RESTORATION OF THE WEST BEAR CREEK UNIT, SAN LUIS NATIONAL WILDLIFE REFUGE

Gerrit A. Platenkamp[*1], D. Tibbitts[2], M.D. Harvey[3], and S. Frazer[4]

[1]**Jones and Stokes, 2600 V street, Sacramento, CA 95818**
Phone: 916-737-3000, Fax: 916-737-3030, e-mail: gerritp@jsanet.com

[2]**Ayres Associates, 2151 River Plaza Drive, Suite 170, Sacramento, CA 95833**

[3]**Mussetter Engineering, Inc., 1730 South College Ave. Suite 100, Fort Collins, CO 80525**

[4]**San Luis National Wildlife Refuge, P.O. Box 2176, Los Banos, CA 93635**

This CALFED-funded study analyzed the effects of controlled levee breaches on nonstructural flood stage reduction, ecosystem attributes, and infrastructure in the San Luis National Wildlife Refuge's (NWR) West Bear Creek Unit and on adjacent lands. UNET hydraulic models were used to predict the extent and depth of inundation in overbank areas under existing conditions and for four alternative configurations of openings in the San Joaquin River's left bank levee. Floodplain sediment deposition and bank erosion potential were analyzed using the results of site-specific HEC-2 models.

Both benefits and minor negative impacts on local infrastructure would result from the floodplain restoration project. Downstream of the project area, the maximum stage reduction is somewhat limited compared to existing conditions; estimated stage reduction for a 25-year flood event ranges from 0.04 to 0.13 feet, depending on the alternative. Locally, however, the San Joaquin River's stage reduction could reach 1.45 feet. The estimated volumes of sand-sized sediment delivered to the overbank areas during a 25-year event range from approximately 2,300 to 17,500 cubic yards.

The project would only cause small changes in the potential for bank erosion. Restoring periodic flooding would expand the size of wetland habitats and make them available to wildlife for longer periods during the breeding season, and shallow inundated floodplain areas would provide habitat for several native fish species. In addition, many special-status species that have been documented at the San Luis NWR Complex would benefit from periodic flooding. Periodic inundation could adversely affect two federally listed invertebrates in the short term, however.

CUMULATIVE ECOLOGICAL RISK ASSESSMENT – A FRAMEWORK FOR DEVELOPING EXPLICIT CONCEPTUAL MODELS IN CMARP PROGRAM DESIGN

Nicholas N. Poletika*

Dow AgroSciences LLC, 9330 Zionsville Road, Indianapolis, IN 46268
Phone: 317-337-3476, Fax: 317-337-3214, e-mail: npoletika@dowagro.com

Multiple stressors are the norm in the Bay-Delta system and watersheds, and they exist at various spatial and temporal scales. Numerous examples can be found in the Bay-Delta Program primary objectives of water quality, ecosystem quality, water supply, and vulnerability of Delta functions. The CMARP monitoring and research program design process recognizes the presence of multiple stressors and deals with them through the use of explicit conceptual models. However, the models developed to date are for single stressors only. A framework is necessary to account for multiple stressors so that important interactions will be considered, prioritization of monitoring and research areas can take place, and appropriate adaptive management measures occur at each iteration of the process. This paper recommends adoption of the cumulative ecological risk assessment paradigm as the framework for CMARP design, as described in the 1998 USEPA Guidelines for Ecological Risk Assessment. Examples of explicit conceptual models for a single-stressor chemical contaminant and multiple stressors operating simultaneously in an aquatic ecosystem illustrate the advantages gained by employing the cumulative ecological risk assessment paradigm. Improvement in conceptual model design results primarily in the area of uncertainty analysis. Correct specification of relationships between stressors insures more accurate risk characterization, and, consequently, increases efficiency in all activities supporting adaptive management. Additional benefits include better definition of knowledge gaps in ecosystem function and identification of important secondary effects.

DISSOLVED OXYGEN AND TEMPERATURE MODELING OF THE DELTA

Hari L. Rajbhandari* and P. Nader

California Department of Water Resources, 1416 Ninth Street, Sacramento, CA 95814
Phone: 916-57-5171, Fax: 916-53-6077, e-mail: hari@water.ca.gov

DSM2, one-dimensional hydrodynamics and water quality model, has been enhanced to characterize the spatial and temporal distributions of important water quality variables in the Sacramento-San Joaquin Delta. The model is capable of simulating the dynamics of dissolved oxygen including primary production, nutrients and temperature. Using a dynamic flow field obtained from the hydrodynamic module, the water quality module performs advective and dispersive steps of mass transport including net transfer of energy at the air-water interface. Changes in mass of constituents due to decay, growth and biochemical transformations are simulated utilizing interconstituent relationships derived from the literature.

Calibration and verification of the model were performed using field observation of temperature and dissolved oxygen, considering nutrient balances over a succession of tidal cycles. The model results closely matched observed dissolved oxygen concentration and temperature in the San Joaquin River near Stockton, where dissolved oxygen levels frequently fall below 5 mg/l during warm, dry months.

Low dissolved oxygen levels are of concern because they may adversely affect resident fish and other aquatic life. The model may be used to identify the main factors that contribute to low dissolved oxygen situation in this reach of the San Joaquin River. Through evaluations of different scenarios, the model can aid in developing potential management strategies to address water quality degradation in the Delta. The Department of Water Resources' Delta Modeling Section is coordinating with the San Joaquin River Dissolved Oxygen Total Maximum Daily Load (TMDL) Stakeholder process and the CALFED Bay-Delta Program in development of the model.

MONITORING THE CLIMATIC CONTEXT OF CALFED-OPPORTUNITIES AND OPTIONS

Kelly Redmond

Western Regional Climate Center, Desert Research Institute, 2215 Raggio Parkway, Reno, NV
Phone: 775-674-7010, Fax: 775-674-7016, e-mail: wrcc@dri.edu

The consequences and outcomes of CALFED plans and actions can only be understood if they can be placed in their proper long-term, large-scale climatic, oceanographic, and hydrologic contexts. Thus, the physical manifestations of climate and weather that affect the Delta and its biological inhabitants need to be monitored, and the monitoring products must be integrated in a multidisciplinary sense, to provide the required contexts. Existing networks provide opportunities to supply most of the required interpretations. However, the integration of these varied existing data sets and data collection programs (scattered through different agencies and groups) is complex and requires planning and support and the involvement of experienced personnel. Current networks and operational relationships will be reviewed and a conceptual framework for using them to CALFED's advantage will be offered. Methods for more easily and efficiently accessing data archives are needed. A more complete infrastructure for acquiring, storing, distributing, displaying, and manipulating archived values is greatly desired by all participants.

BREACHING LEVEES FOR TIDAL WETLAND RESTORATION: WHAT SHOULD WE EXPECT IN THE DELTA?

Denise J. Reed[*1], L.F. Grimaldo[2], Z. Hymanson[2], M. Orr[3], P. Williams[3], and C. Simenstad[4]

[1]**Department of Geology and Geophysics, University of New Orleans, New Orleans, LA 70148 Phone: 504-280-7395, Fax: 504-280-7396, e-mail: djreed@uno.edu**

[2]**California Department of Water Resources, 3251 S Street, Sacramento, CA 95816**

[3]**Philip Williams & Assoc., 770 Tamalpais Drive, Suite 401, Corte Madera, CA 94925**

[4]**School of Fisheries, Box 355020, University of Washington, Seattle, WA 98195-5020**

Field studies of both breached levee and natural remnants of Delta wetlands have demonstrated the importance of biotic or morphological attributes of intertidal and subtidal environments in providing habitat for species of concern. Our studies of breached levee sites of different ages indicate the rates at which some of these attributes change after levee breach, and some of the controlling factors. As in any tidal wetland system, elevational controls on water depth and flooding regime have been identified as fundamental influences on both the character and nekton utilization of shallow water environments. We present a conceptual model of tidal wetland development in breached levee sites which encompasses relationships among sea-level rise, land subsidence, and sediment supply and shows how biotic and morphological attributes change after breach. Our improved understanding of how substrate elevation controls colonization by emergent vs. submerged macrophytes; how river discharge, sediment supply and tidal action modulate changes in substrate elevation; and which fishes are associated with certain biotic and morphological site characteristics, allows projections of the type of habitat provided at various stages post-breach. Interventions to accelerate or modify natural changes in substrate elevation and/or the physical dynamics within the breached levee sites can now be planned with more certain expectation of the consequences to fishes. These expectations can be tested and refined in the Delta through experimental design and detailed monitoring of future breached levee projects with the ultimate goal of implementing projects that optimize for water quality improvements and habitat provision for fishes. The conceptual model developed for breached levee sites in the Delta will be tested as part of the BREACH II study in Suisun and North Bay wetlands to further clarify the effect of gradients in salinity, riverine and tidal forcing, and sediment supply on the provision of habitat for fishes of concern.

OCCURRENCE AND POTENTIAL IMPACTS OF OP PESTICIDES IN CENTRAL VALLEY URBAN CREEKS

Kathleen M. Russick*[1] and L. Nash[2]

[1]**Russick Environmental Consulting, 9359 Savin Place, Elk Grove, CA 95624**
Phone: 916-686-6008, Fax: 916-264-1497, e-mail: andykath@inreach.com

[2]**City of Sacramento, Department of Utilities, 1395 35th Ave., Sacramento, CA 95822**

The organophosphorus (OP) pesticides diazinon and chlorpyrifos have been identified by the Sacramento Stormwater Management Program as the highest priority pollutants in Sacramento area urban creeks. The Central Valley Regional Board and other water agencies in the region and within the state have also determined that the occurrence of these OP pesticides in urban creeks are of major concern. In 1997 the Sacramento Stormwater Program initiated a major CALFED-funded study to evaluate and eliminate the toxicity of these pesticides in their urban creeks. The ultimate goal of the effort is to rehabilitate Sacramento urban creeks so that they can support healthy biotic communities. An assumption of this study is Sacramento urban creeks are representative of other urban creeks in the Central Valley. The study evaluated data it generated, both pesticide concentrations and associated toxicity, and historic data. This evaluation of diazinon and chlorpyrifos concentrations in Sacramento urban creeks generated the following findings:· Diazinon and chlorpyrifos occur at toxic concentrations throughout the year in Sacramento urban creeks. When evaluated individually, each pesticide is acutely toxic to arthropods 16% of the time. When their toxic effects are evaluated in combination, these pesticides are acutely toxic to arthropods 40% of the time. These findings were so definitive, that plans for further phases of the study, to collect additional pesticide concentration data, are being deferred. The Sacramento Program is developing and implementing an aggressive public education and awareness plan designed to change peoples' behavior to reduce the amount of pesticides that are allowed to reach urban creeks. Additionally, the Stormwater Program is recommending that bioassessment monitoring be conducted in representative area creeks in order to identify and rank the multiple stressors on urban creeks. This bioassessment monitoring would try to determine the significance of OP pesticides among these multiple urban creek stressors.

MONITORING WHITE STURGEON YEAR CLASS STRENGTH IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

Raymond G. Schaffter*

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: rschafft@delta.dfg.ca.gov

The highly variable nature of Sacramento-San Joaquin Estuary white sturgeon year-class strength affects abundance and the quality of the sport fishery. The tagging program for legal-sized (117 to 183 cm) fish is inadequate to accurately index annual production because legal-sized fish are old (generally age 10) and, thus, more difficult to age and subject to more growth variability than younger fish. In 1991, to better index year-class strength and to predict recruitment to the sport fishery, a baited setline survey, targeting 2-7-year-old fish, was initiated. Methods and gear were standardized in 1996 and 21 locations have been sampled annually since then. Age composition of the catch is estimated from length frequency distributions and an age-length key derived from an aged subsample of the catch. This survey has demonstrated that white sturgeon reproductive success was low during the 1987-1992 drought, but has been high during many of the wet years since 1993. This has implications for the fishery, as the recent (1998) high population of legal-sized white sturgeon is presently declining as the drought year classes are now being recruited. A resurgence of the population and the fishery will not take place until at least 2006 through 2010, when several of the post-drought year classes are recruited.

SUSPENDED-SEDIMENT SUPPLY TO THE DELTA FROM THE SACRAMENTO RIVER

David H. Schoellhamer* and R.L. Dinehart

U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA 95819
Phone: 916-278-3126, e-mail: dschoell@usgs.gov

The U.S. Geological Survey measures sediment transport in the Delta primarily to describe the movement of sediment affecting habitats and the availability of sediment needed for habitat restoration and levee construction.

The Sacramento River is the primary supplier of suspended sediment to the Delta. From 1961 to 1998, the suspended-sediment discharge of the Sacramento River was seven times greater than that of the other main Delta tributary, the San Joaquin River. During water year 1999, 45 percent of the annual suspended-sediment discharge at the gaging station on the Sacramento River at Freeport occurred during winter months.

During a typical flow pulse past Freeport, two peaks in suspended-sediment concentration are observed: an immediate rise to peak in response to local resuspension, and a smaller, broader peak 4 to 5 days later. As flow increases, resuspension decreases the supply of erodible sediment on the bed, therefore, the first peak begins to diminish in 1 to 2 days. Flow pulses of similar size later in the season resuspend less sediment. The second smaller peak is most likely finer sediment derived from watershed sources far from Freeport.

Both peaks move downstream to Rio Vista in less than a day. Unlike Freeport, pronounced resuspension did not occur at Rio Vista during water year 1999 because bi-directional tides dominated the flow pulse. The finer sediment of the second peak settles more slowly and thus the second peak was greater than the first peak at Rio Vista.

Sediment is deposited between Freeport and Rio Vista because flow in the River changes from unidirectional to bi-directional and velocity decreases as the channel widens. During winter of water year 1999, suspended-sediment discharge at Freeport exceeded the tidally averaged discharge at Rio Vista by 2.9 x 108 kg, even though discharge at Rio Vista included discharge from the Yolo Bypass.

OCEAN CLIMATE AND VARIABILITY: PATTERNS AND IMPLICATIONS

Franklin B. Schwing[*1] and W.J. Ingraham[2]

[1]**Pacific Fisheries Environmental Laboratory, NOAA/NMFS, 1352 Lighthouse Avenue, Pacific Grove, CA 93950-2097, Phone: 831-648-9034, Fax: 831-648-8440, e-mail: fschwing@pfeg.noaa.gov**

[2]**NMFS/AFSC, 7600 Sandpoint Way NE, Seattle, WA, 98115-6349**

Coastal ocean features and processes off California are part of a global system that is strongly coupled with the atmosphere. Coastal currents, temperatures, and upwelling, for example, are characterized by distinct seasonal patterns of their distribution, evolution, and coupling. Likewise, interannual fluctuations from ENSO to global climate change scales are reflected in local anomalies from a typical ocean state (usually some arbitrary statistical mean). These perturbations impact weather in the coastal zone. They also affect marine and estuarine populations by altering the transport of nutrients, food resources, and recruiting larvae and juveniles; changing thermal effects on metabolism and development; and modifying the health and sustainability of ocean and estuarine habitats.

From historical data sets and model output, reasonable representations of past ocean conditions can be generated. Scientists use this information to define periods of unusual climate and shifts in climate regimes. These can then be compared to changes in biological indicators (e.g., commercial and recreational catch, harmful algal bloom incidents), to isolate the effects of natural ocean variability on coastal ecosystems and improve our understanding of the mechanisms by which ecosystems are impacted by climate and climate change. We will describe the major ocean features and patterns associated with climate variability and cite some examples of linkages between climate and marine/estuarine populations, with an eye towards placing CALFED decision making in its proper oceanographic context.

THE PROSPECT AND PITFALLS OF BREACHING LEVEES FOR TIDAL WETLAND RESTORATION

Charles A. Simenstad[*1], J.R. Cordell[1], J.D. Toft[1], D.J. Reed[2], M. Orr[3], P. Williams[3], L.F. Grimaldo[4], and Z. Hymanson[4]

[1]**Wetland Ecosystem Team, School of Fisheries, University of Washington, Seattle, WA 98195-5020 Phone: 206-543-7185, Fax: 206-685-7471, e-mail: simenstd@u.washington.edu**

[2]**Dept. of Geology and Geophysics, University of New Orleans, New Orleans, LA 70148**

[3]**Philip Williams & Associates, 770 Tamalpais Drive, Suite 401, Corte Madera, CA 94925**

[4]**California Department of Water Resources, 3251 S Street, Sacramento, CA 95816**

Isolation from tidal inundation by construction of levees or dikes and the installation of tide gates has accounted for much of the wetland loss due to coastal development in temperate North America, as well as other regions of the world. Estuarine marshes have been the most prominently impacted systems, where typically 25%-95% of the total historic wetland area has been entrained behind levees. The consequential impact to coastal ecosystems has not been evaluated scientifically, but is believed to significantly modify estuarine hydrology, truncate and simply food webs, and diminish critical habitat of migratory fish and wildlife. Conversely, restoration of these historical wetlands by breaching levees is considered to be both an effective and economical strategy to recovering many of these lost ecosystem functions at a landscape scale. However, how rapidly, through what developmental trajectories, and even whether these breached-levee wetlands will attain functionality equivalent to natural wetlands is extremely contingent on several critical issues: (1) the extent of subsidence since levee construction; (2) historical modifications of watershed and tidal hydrology and sediment sources in the watershed and estuary; (3) the extent to which invasive species have modified the estuarine ecosystem; and (4) design approaches to breaching levees and restoring tidal inundation. While many estuarine breached-levee restorations have demonstrated phenomenally rapid redevelopment and functionality, the prognosis for breached-levee restoration is uncertain in estuaries such as the Sacramento-San Joaquin Delta and San Francisco Bay, where the legacy of watershed and estuarine modifications is extreme. Our BREACH research to understand processes and situations that influence the development rate and patterns of desirable attributes should contribute significantly to reducing the uncertainty of restoring wetlands in the Delta and Bay, although it may not satisfy the urgency for instant restoration.

CALFED UC DAVIS DELTA MERCURY STUDY: YEAR 2 FINDINGS

Darell G. Slotton[*1], T.H. Suchanek[2], and S.M. Ayers[1]

[1]**Dept. of Environmental Science and Policy, University of California, 1 Shields Ave., Davis, CA 95616, Phone: 530-756-1001, Fax: 530-752-3350, e-mail: dgslotton@ucdavis.edu**

[2]**Dept. of Wildlife, Fish, and Conservation Biology, University of California, 1 Shields Ave., Davis, CA 95616**

In this presentation, we will discuss important new findings of this three year, Delta-wide mercury study. We will also discuss approaches for assessing the mercury methylation question throughout this highly variable system.

Methyl mercury efflux from standard sediment cores, as measured in laboratory experiments, was found to generally occur at relatively low levels, prohibiting the meaningful quantitation of this parameter across the system with standard techniques. A viable laboratory approach, however, was developed to assess the potential for various Delta sediments to methylate new mercury. This parameter varied spatially. Methylation of new mercury was found to peak at 2-6 days, with apparent demethylation subsequently ramping up in some sediments. Methylation potential was 4 to 30-fold greater in organic-rich depositional wetland areas, as compared to adjacent channels and flats. Sediment mercury and related parameters were analyzed from 75 sites.

Naturally occurring biota provided the strongest measure of relative in-situ mercury exposure throughout the varied locales and habitats of the Delta. We focused on organisms exhibiting high levels of site fidelity, low intra-site variability in mercury uptake, and presence throughout the system. *Corbicula* clams and inland silversides were sampled consistently at over 60 diverse sites. Data from these and other samples provide a new picture of mercury dynamics in the Delta. Individual mercury uptake was quite variable in some species and at certain size ranges, but consistent in others. Benthic clams and planktonic silversides exhibited somewhat different mercury spatial patterns.

Seasonal and inter-annual shifts in mercury bioavailability may be significant. Central Delta flooded tracts were among the lowest mercury bioaccumulation regions, despite elevated methylation potential. Bioaccumulation was greatest in general proximity to Coast Range and Sierra Nevada mining sources, with an important additional elevated zone in the West Delta, possibly linked to the entrapment zone and fresh/saline mixing region.

DETERMINANTS OF RIPARIAN BIRD SPECIES ABUNDANCE AND DIVERSITY: COMPARISON OF RIPARIAN FOREST AND RESTORATION SITES IN THE SITES IN THE CENTRAL VALLEY AND COMPARISON AMONG WATERSHEDS

Stacy Small*, Nadav Nur, and G.R. Geupel

Point Reyes Bird Observatory, Stinson Beach, CA

Point Reyes Bird Observatory's Sacramento River landbird monitoring project seeks to identify areas of high biodiversity and landbird productivity and determine habitat features associated with primary (demographic) and secondary (species richness, diversity, and abundance) population parameters, in order to guide and evaluate land management actions including acquisition, preservation, and restoration. This pro-active adaptive management approach is taken with the dual goal of 1) reversing regional population declines of neotropical migrant and resident species and 2) promoting the recolonization of extirpated or rare species, both listed and unlisted. We modeled the relationship of abundance of four riparian bird species (American Robin, American Goldfinch, Black-headed Grosbeak, and Spotted Towhee) to fine scale habitat features and found that the suites of variables that influence abundance vary across species and space (comparing the Sacramento, Cosumnes, and San Joaquin watersheds). We also developed a model that depicts an increase in riparian bird diversity on restoration sites over an eight-year interval, indicating that as these sites mature, biodiversity increases. Finally, we examined nest success of three riparian bird species and compared results across two treatment types, restoration and remnant riparian forest. We found that nest success is extremely low overall for two ground/shrub nesting species (lazuli bunting and spotted towhee) and moderate for one mid-canopy nesting species (black-headed grosbeak). Nest success was similar on both restoration and forest sites for all three species. Low nest success on the Sacramento River can be primarily attributed to nest predation for spotted towhee and a combination of nest predation and brown-headed cowbird parasitism for lazuli bunting. Our results indicate that poor productivity may well be the demographic factor driving population declines of many open-cup nesting species in the Sacramento Valley. Future research will seek to identify nest predators and relate productivity to nest predator populations and other biological and physical river processes.

MULTI-LEVEL STUDY OF ENVIRONMENTAL ENDOCRINE DISRUPTOR EFFECTS IN AN ESTUARINE CRUSTACEAN

Mark J. Snyder[*1], F.J. Griffin[1], G.N. Cherr[1], and H.V.S Peeke[2]

[1]**Bodega Marine Laboratory, University of California-Davis, Bodega Bay, CA 94923**
Phone: 707-875-1964, e-mail: mjsnyder@ucdavis.edu

[2]**University of California, San Francisco, CA**

Environmental endocrine disruptors (EDCs) are a growing group of diverse compounds from various human activities. EDCs either mimic the action of, or somehow interfere with normal endocrine functions. These effects have been well demonstrated in vertebrates, but there is only a single well-characterized example of such effects in an aquatic invertebrate (gastropod mollusc). We present our ongoing research plan to examine the effects of EDCs on the estuarine shrimp, *Palaemon macrodactylus*, a species widely distributed within the San Joaquin Delta and associated tributaries such as the Petaluma River. Our work includes analyses of embryonic development, larval feeding and swimming behaviors, and biochemical markers. Our goal is to determine the relative risks that EDCs may have on the lifecycle of important estuarine invertebrates.

ORGANIC MATTER BIOAVAILABILITY AMONG HABITATS AND HYDROLOGIC INPUTS IN THE SACRAMENTO AND SAN JOAQUIN RIVER DELTA

William V. Sobczak*, J. Cloern, B. Cole, T. Schraga, A. Arnsberg, and J. Edmunds

U.S. Geological Survey, 345 Middlefield Rd., MS-496, Menlo Park, CA 94025
Phone: 650-329-4731, Fax: 650-329-4463, e-mail: WSobczak@usgs.gov

We have assessed the sources, quantity, composition, and bioavailability of organic matter in the Sacramento and San Joaquin River Delta among a diversity of habitats and hydrological inputs. In this paper, we examine variation in the amounts and bioavailability of dissolved organic carbon (DOC) and particulate organic carbon (POC). Organic carbon bioavailability was assessed with bioassays in which organic carbon loss and microbial respiration were measured. These bioassays enable us to partition organic matter into four pools: refractory DOC, bioavailable DOC, refractory POC, and bioavailable POC. The size of these pools and, more subtly, the relative size of these pools are ecologically relevant because they provide the potential energy for trophic transfer and insight into the routing of this energy into the planktonic food web. In general, a small fraction of the total pool of organic matter is bioavailable to bacterioplankton. This pool of bioavailable organic matter is routinely dominated by bioavailable DOC, however habitats and hydrologic inputs that support high algal biomass can supply large amounts of bioavailable POC per volume. More specifically, water from the Sacramento River appears to deliver less bioavailable organic matter (when normalized to volume) than water from the San Joaquin River suggesting that the routing of water through the Delta can alter organic matter bioavailability in Delta habitats. Habitats that episodically support high algal biomass can provide large amounts of bioavailable organic matter per volume suggesting that the construction of shallow water habitats that promote high primary production may generate more bioavailable organic matter within the Delta. However, the relative contribution of bioavailable organic matter in the Delta's riverine inputs and existing shallow water habitats is small compared to the contribution from sloughs draining Suisun Marsh suggesting that much larger pools of bioavailable organic matter were historically present in the Delta.

TREE-RING RECONSTRUCTION OF SAN FRANCISCO BAY SALINITY: 1604-1997

David W. Stahle and M.D. Therrell

Tree-Ring Laboratory, Department of Geosciences, University of Arkansas, Fayetteville, AR 72701
Phone: 501-575-3703, e-mail: dstahle@comp.uark.edu

Blue oak (*Quercus douglasii*) tree-ring chronologies from California are highly correlated with winter-spring precipitation, Sacramento-San Joaquin streamflow, and with salinity in San Francisco Bay. A regional average of five blue oak chronologies explains 81% of the interannual variability of seasonalized salinity measured at the Golden Gate from 1922-1952 (Fort Point), a period preceding the massive diversion of freshwater from the Sacramento-San Joaquin system. The reconstruction indicates that the post-diversion salinity extremes witnessed in San Francisco Bay after 1952 have been unprecedented over the past 400 years, particularly during the record California droughts of 1976-1977 and 1987-1992. These recent extremes and the 2.52ä increase in average January-July salinity measured at Fort Point from 1953-1994 appear to largely reflect the anthropogenic appropriation of Sacramento-San Joaquin streamflow. This new tree-ring reconstruction generally confirms the low frequency salinity fluctuations in San Francisco Bay estimated from lower resolution, but much longer sedimentary data.

BIOACCUMULATION OF SELENIUM IN THE FOOD WEB OF SAN FRANCISCO BAY: IMPORTANCE OF FEEDING RELATIONSHIPS

A. Robin Stewart[*1], S.N. Luoma[1], M. Doblin[2], K. Hieb[3], and K. Miles[4]

[1]**U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025**
Phone: 650-329-4550, Fax: 650-329-5590, e-mail: arstewar@usgs.gov

[2]**Department of Ocean Sciences, Old Dominion University, 4600 Elkhorn Ave., Norfolk, VA**

[3]**California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205**

[4]**U.S. Geological Survey, University of California, One Shields Ave. Davis, CA 95616**

Elevated selenium (Se) concentrations in San Francisco Bay (SFB) in the bivalve, Potamocorbula amurensis, and benthivorous diving ducks (e.g. Scaup) and selected fish indicate that Se contamination could impede restoration of some fish populations. A study of the trophic transfer of Se through the SFB food web was designed to identify which species were most threatened by Se. In 1999, higher selenium concentrations were found in a bivalve-based food web than a crustacean-based food web. Se bioaccumulation was also location-dependent, apparently influenced by sources within the estuary. Stable isotopes identified feeding relationships within the food webs and general feeding ranges: ^{13}C identified sources of organic matter and varied with position in the estuary; ^{15}N identified predator/prey relationships and the effect of organic matter recycling on Se in bivalves; and ^{34}S identified feeding locations and migratory ranges of fish in the estuary. Sample collection for trophic relationships was restricted to fall 1999, to control for seasonal variations in stable isotopes and Se accumulation. The suspension feeding amphipod *Corophium* had similar ^{15}N values to *Potamocorbula* suggesting a similar trophic position in the food web, but amphipods were also enriched in ^{13}C by 2 per mil indicating a difference in food source. Isopod species appear to be feeding at a higher trophic level (3 per mil) than the amphipods and clams, but share a similar carbon source with the amphipods. Clams had 10-fold higher Se concentrations than both amphipods and isopods. Scaup from SFB were approximately 3 per mil higher in 15N than clams and the range of ^{13}C values spanned those for clams. Se concentrations varied widely in Scaup flesh (0.7 to 9.3 microgram Se/g). The highest Se concentrations were in individuals feeding on clams (as indicated by ^{15}N).

METHYL MERCURY BIOACCUMULATION IN RE-FLOODED WETLANDS IN THE SAN FRANCISCO BAY-DELTA ECOSYSTEM

Thomas H. Suchanek[*1], D.G. Slotton[2], S. Ayers[2], and D.C. Nelson[3]

[1]**Dept. of Wildlife, Fish & Conservation Biology, University of California, 1 Shields Ave., Davis, CA 95616, Phone: 530-752-9035, Fax: 530-752-4154, e-mail: thsuchanek@ucdavis.edu**

[2]**Dept. of Environmental Science and Policy, University of California, 1 Shields Ave., Davis, CA 95616**

[3]**Dept. of Microbiology, University of California, 1 Shields Ave., Davis, CA 95616**

Flooded wetlands often produce significantly elevated levels of methyl mercury, even where in-situ mercury concentrations are low. Wetland habitats also regularly promote mercury methylation at enhanced rates. Because some of the projected restoration projects for the San Francisco Bay-Delta system, and at Clear Lake in the Upper Cache Creek watershed, involve the intentional breaching of existing levees, with subsequent flooding of adjacent areas to create "restored" (reflooded) wetlands, there is some significant risk that these restoration activities will increase levels of toxic methyl mercury entering the Bay-Delta ecosystem. Some reclaimed agricultural tracts within the Bay-Delta system have been breached by storms over the past 2 to 75 yrs. Our project is evaluating numerous tracts of wetland habitats within the Bay-Delta to determine whether the age-since-reflooding of these tracts has a significant effect on methyl mercury concentrations in biota. In addition, we are evaluating other potential drivers of methyl mercury production/ bioaccumulation that may explain regional trends in biotic mercury concentrations, such as origin of source waters, gradients in salinity, organic matter, and other toxic contaminants (e.g. selenium). Source waters, such as those originating from the Sulphur Bank Mercury Mine in Clear Lake, may ultimately prove the most significant. Possible remediation strategies for minimizing methyl mercury production/bioaccumulation in these tracts may involve: (1) reducing upstream mercury loading from mining sites such as the Sulphur Bank Mercury Mine at Clear Lake or the Abbott Mine (both of which feed into Cache Creek), (2) selecting sites for wetland restoration that have a lower potential for production/bioaccumulation of methyl mercury and/or (3) utilizing source waters with a lower potential to produce methyl mercury for restoration of wetland habitats. Preliminary data on biotic mercury concentrations and microcosm experiments to determine the potential for methyl mercury production will be given by Dr. Darell Slotton in a follow-up presentation.

DEVELOPMENT OF FISH SCREEN CRITERIA USING THE FISH TREADMILL

Christina Swanson*[1], P.S. Young[1], J.J. Cech Jr.[1], R. Fujimura[2], T. Frink[3], and S. Mayr[3]

[1]**Department of Wildlife, Fish, and Conservation Biology, 1 Shields Ave., University of California, Davis, CA 95616, Phone: 530-752-8659, Fax: 530-752-4154, e-mail: cswanson@ucdavis.edu**

[2]**California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205**

[3]**California Department of Water Resources, 3251 S Street, Sacramento, CA 95816**

Installation of fish screens to reduce water diversion impacts is an important component of CALFED's Ecosystem Restoration Program. However, for some priority species, present fish screen criteria may be inadequate or overly protective. The Fish Treadmill Project was designed to provide information to improve design, operation, and adaptive management of screened water diversions in the Sacrament-San Joaquin watershed. In this paper, we describe the conceptual model, experimental design and methods used in these studies, report selected results for delta smelt, splittail and chinook salmon, and discuss their utility for development of more effective fish screen criteria.

The Fish Treadmill, an annular flume incorporating a 3-m diameter inner fixed fish screen and a 4.3-m diameter rotatable outer screen to enclose a 0.67-m wide test channel, is capable of testing small fishes under a range of approach (through screen) and sweeping (past screen) flow combinations. Studies with this apparatus provide unique opportunities for detailed examinations of the interactive effects of multiple flow vectors on fish-fish screen interactions during both day (light conditions) and night (dark conditions), including frequency and severity of fish-fish screen contact, swimming behavior and downstream screen passage rates, and post-exposure injury, stress, and survival. For most species, screen contact rates (contacts/fish*min) were related to approach and/or sweeping velocities and, for some, screen contact frequency during the experimental exposure was directly related to injury and mortality rates. Nighttime screen contact rates were consistently and significantly higher than daytime rates. Contact severity, measured as degree of contact (e.g., body vs. tail contact) or impact velocity (cm/s), varied with flow for some species. There were substantial differences in the frequencies and effects of impingement (prolonged screen contact), and downstream passage rates among species, life history stages, and time of day. Research supported by DWR, DFG, USBR, and CALFED.

SALT PONDS AND AVIAN COMMUNITIES: WILL BENEFITS OF TIDAL WETLAND RESTORATION EXCEED COSTS TO WATERBIRDS?

John Y. Takekawa[*1], G.M. Martinelli[1], A.K. Miles[2], S. Fregien[2], D.H. Schoellhamer[3], W.G. Duffy[4], and M.K. Saiki[5]

[1]**U.S. Geological Survey, Western Ecological Research Center, San Francisco Bay Estuary Field Station, P.O. Box 2012, Vallejo, CA 94592, Phone: 707-562-2000, Fax: 707-562-3001, e-mail: john_takekawa@usgs.gov**

[2]**U.S. Geological Survey, Western Ecological Research Center, Davis Field Station, 1 Shields Ave., 278 Kerr Hall, Davis, CA 95616**

[3]**U.S. Geological Survey, Water Resources, 6000 J Street, Placer Hall, Sacramento, CA 95819**

[4]**U.S. Geological Survey, California Cooperative Fishery Research Unit, Humboldt State University, Arcata, CA 95521**

[5]**U.S. Geological Survey, Western Fisheries Research Center, Dixon Duty Station, 6924 Tremont Road, Dixon, CA 95620**

The 14,000 ha of artificial salt evaporation pond systems in the San Francisco Bay estuary have become an integral part of the ecosystem in the past century and provide critical habitat for migratory waterbirds. These hypersaline systems typically support simple assemblages of macroalgae and macroinvertebrates, but despite their seeming lack of biodiversity, they support a surprisingly large number of avian species. However, we lack general information on processes within these hypersaline systems, and we can't predict how recently proposed conversion of these wetlands to tidal marshes may affect existing waterbird populations. Thus, we initiated an interdisciplinary research study in January 1999 on former salt ponds along the Napa River. We examined nutrient concentrations, primary productivity, pelagic and benthic invertebrates, estuarine fishes, and waterbird abundance and distribution. We conducted monthly waterbird surveys to select 10 grids used by birds in each of 4 ponds representing different salinities for sampling fish, invertebrates, and water quality bimonthly. Overall, we found a correlation between increasing salinity and decreasing taxa richness in all groups except waterbirds. We identified 66 species of waterbirds representing six foraging guilds including surface feeders, shallow probers, deep probers, dabblers, diving benthivores, and piscivores. Total species and species diversity was higher in baylands compared with salt ponds during all four seasons; however, bird densities were higher in salt ponds in the winter and spring, primarily because of large concentrations of benthivores. Cessation of salt production in 1992 resulted in a sharp decline of some diving duck populations in the North Bay. Thus, salt ponds provide valuable habitats for waterbirds with different biotic communities depending on salinity and water depth. While benefits of converting existing salt ponds to tidal wetlands is difficult to predict, the costs will likely be a reduction in densities of some avian species.

A NEW MODULAR SCREEN SYSTEM FOR PROTECTING FISH AT WATER INTAKES

Edward P. Taft III[*1] and D.A. Dixon[2]

[1]**Alden Research Laboratory, Inc., 30 Shrewsbury Street, Holden, MA 01520**
Phone: 508-829-6000 ext. 410, Fax: 508-829-5939, e-mail: ntaft@aldenlab.com
[2]**Electric Power Research Institute, 7905 Berkeley Drive, Gloucester Point, VA 23062**

A new type of fish diversion screen, known as the Modular Inclined Screen (MIS), has been designed to provide effective fish protection at any type of water intake. Because the screen operates at water velocities of up to about 3 m/s in the approach channel, the MIS is more compact and cost-effective than existing low-velocity screens. The MIS consists of an entrance with trash racks, dewatering stop log slots, a wedge-wire screen set at an angle to the flow between 10 and 20 degrees, and a bypass for guiding diverted fish to a transport pipe or channel. The screen is composed of 50% porosity bar with 1.9-mm spacing and is mounted on a pivot shaft so that it can be cleaned by backflushing. The screen in a full-scale module would be 9.1 m in length by 3.0 m in width, with the capacity to screen up to 28.3 m3/s at a channel velocity of 3.0 m/s. The module is completely enclosed and is designed to operate at water velocities ranging from about 0.6 to 3.0 m/s.

The biological effectiveness of the MIS has been evaluated in laboratory tests conducted with eleven fish species and in a pilot-scale field evaluation conducted with six fish species (primarily juveniles): Atlantic, chinook and coho salmon, rainbow trout, brown trout, walleye, yellow perch, largemouth and smallmouth bass, American shad, river herring, channel catfish, and shiners. The combined laboratory and field tests showed diversion effectiveness of nearly 100 percent with little or no latent mortality for most species over a range of test conditions. These evaluations have demonstrated that the MIS has the potential to successfully divert a diverse group of species at water intakes. The MIS offers a cost-effective alternative for fish screening at intakes throughout the Bay-Delta region.

SEDIMENT QUALITY ASSESSMENTS IN SAN PABLO BAY AND SUISUN BAY

Bruce E. Thompson[*1], S. Lowe[1], J. Hunt[2], and B. Anderson[2]

[1]**San Francisco Estuary Institute, 1325 S. 46th St., Richmond, CA 94804**
Phone: 510-231-5613, Fax: 510-231-9414, e-mail: brucet@sfei.org
[2]**Department of Environmental Toxicity, UC Davis, Davis, CA 95616**

Assessments of sediment quality may be useful to CALFED for determining the adequacy of sediment habitats to maintain natural populations, identifying areas where remediation is needed, and evaluating reuse of dredged material for restoration. A weight-of-evidence approach was used that considered information about sediment contamination, toxicity, and benthos sampled in San Pablo, and Suisun Bays by several monitoring programs, 1992-1998. Sediment contamination was assessed using an Effects-Range Median (ERM) quotient, a cumulative index based on probabilities for effects of 13 individual contaminants. Sediment toxicity was assessed using laboratory exposures of the amphipod *Eohaustorius estuarius* to bulk sediments, and exposures of mussel embryos to sediment elutriates (water soluble extracts). Benthic assessments were conducted using several commonly measured benthic indicators in an IBI-type approach. None of the 44 samples assessed indicated impacts to all three sediment components. Usually, one or two indicators suggested possible impacts. For example, sites in Castro Cove, near an abandoned refinery outfall, were impacted based on sediment contamination and toxicity, but the benthos did not appear to be impacted. ERM quotients were significantly correlated with amphipod toxicity and the degree of benthic impacts; values above 0.378 were always toxic to amphipods and were always associated with moderate to severe benthic impacts. However, the two bioassays usually produced contrasting results, and neither test accurately predicted benthic impacts. There was no relationship between amphipod mortality in the bioassays and amphipod abundances in the benthic samples. These results may be due to greater sensitivity to contamination by the bioassay amphipods than the resident amphipods, differences in exposures between lab and field samples, or physiological acclimation of resident benthos. Understanding and reconciling differences between sediment bioassays and benthic indicators, and accounting for differences due to natural variations in abiotic factors (e.g. salinity) will be necessary for proper interpretation of sediment assessments.

STABILITY OF DELTA LEVEES

R. Kevin Tillis*

Hultgren-Tillis Engineers, 2520 Stanwell Drive, Suite 100, Concord, CA 94520
Phone: 925-685-6300, Fax: 925-685-6768, e-mail hultgren@pacbell.net

The presentation will include an overview of static slope stability analysis of Delta levees constructed on peat. The author will use data obtained from his involvement on the Delta Wetlands project and on reclamation district projects on, Bacon Island, Bethel Island, Bouldin Island, Holland Tract, King Island, and Webb Tract.

The presentation will outline the existing conditions on Delta islands underlain by peat based on numerous borings, cone penetration tests and personal observation. A summary of existing conditions will be presented including fill types and thicknesses, levee slopes, water levels in and below levees, and material properties of peat (strength and compressibility). The results from test fills on Bouldin Island and instrumented test sections on Webb Tract will be presented.

Typical cross-sections of Delta levees will be shown along with the results of slope stability analysis for the cross-sections. The presenter will list factors that should be considered in design and analysis of these levees. Methods to improve levee stability will be presented.

COMMUNITY EFFECTS OF THE NON-INDIGENOUS AQUATIC PLANT WATER HYACINTH (EICHHORNIA CRASSIPES) IN THE SACRAMENTO/SAN JOAQUIN DELTA

Jason D. Toft*, C.A. Simenstad, and J. Cordell

University of Washington, School of Fisheries, Box 355020, Seattle, WA, 98195
Phone: 206-221-5460, Fax: 206-685-7471, e-mail: jtoft@fish.washington.edu

The South American floating aquatic plant water hyacinth (*Eichhornia crassipes*) is non-indigenous to the Sacramento/San Joaquin Delta, California, and has a history of worldwide invasions. A common native plant that functionally occupies similar habitats as hyacinth in the Delta is pennywort (*Hydrocotyle umbellata*). Based on the utilization of shallow-water vegetated habitats by invertebrates and fish, our main scientific question was: Has hyacinth modified the invertebrate assemblage structure and fish-invertebrate food web as compared to pennywort? To assess this, we sampled invertebrates and physical parameters in patches of hyacinth and pennywort and analyzed surrounding fish diets at three sites in the Delta during 1998 and 1999.

Differences between hyacinth and pennywort were exhibited in both habitat architecture and associated invertebrates. Taxa richness and diversity of all invertebrates were usually higher in pennywort early in the summer, but were higher in hyacinth during maximum growth in later months. Leaf density was higher in pennywort, although hyacinth formed taller canopies. Densities of terrestrial insects were greater in pennywort, and there were significant differences in insect assemblage compositions. Hyacinth roots in the water column had more surface area and biomass, as well as lower surrounding dissolved oxygen levels. Overall densities of epibenthic and benthic aquatic macroinvertebrates were typically greater in pennywort, and taxonomic compositions of aquatic invertebrate assemblages showed significant differences. Amphipods and isopods were particularly abundant living epiphytically in the root masses, including several new introduced species: the amphipod *Crangonyx floridanus*, and the isopods *Caecidotea racovitzai* and *Asellus hilgendorfii*. In general, the native amphipod *Hyalella azteca* was more abundant in pennywort and heavily preyed upon by fish, while the non-indigenous C. floridanus was more abundant in hyacinth and not prevalent in fish diets. Thus, the widespread growth and pervasiveness of hyacinth in the Delta has caused significant ecological ramifications.

BIOLOGICAL EVALUATIONS OF THE GEORGIANA SLOUGH EXPERIMENTAL ACOUSTICAL FISH BARRIER, PHASES I-IV DURING 1993-1996

Kevan A. F. Urquhart[*1], C.H. Hanson[2], and D. Hayes[3]

[1]**Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205**
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: kurquhar@delta.dfg.ca.gov

[2]**Hanson Environmental Inc., 132 Cottage Lane, Walnut Creek, CA 94595**

[3]**CH2M Hill, 2485 Natomas Park, Sacramento, CA 95833-2937**

Juvenile chinook salmon emigrating from the Sacramento River of California and its tributaries can be diverted into the central Delta, where they are susceptible to higher mortality rates. Increased mortality rates reflect, in part, increased predation, delays in migration, increased water temperatures, and increased entrainment losses at the State and Federal Water Projects (SWP and CVP) and other Delta water diversions. If some juvenile chinook salmon could be discouraged from entering the interior Delta through Georgiana Slough by an acoustic behavioral barrier, it might contribute to an increase in survival of all races of salmon during emigration. Guidance of winter-run chinook salmon away from Georgiana Slough might also contribute to a reduction in entrainment losses at the SWP and CVP diversions, and therefore, a reduction in incidental take under CESA/ ESA.

Proposals were considered to physically block the passage of juvenile salmon into Georgiana Slough through installation of a rock barrier or other structures. However, a physical barrier could adversely affect water quality within the slough and Delta, alter the natural flow of water from the Sacramento River through interior Delta channels, affect levee stability and flood control, impede upstream migration of adult fish, and create an obstruction to recreational boating. Therefore, the alternative of a carefully designed behavioral barrier that utilizes the avoidance response of juvenile salmon to reduce diversion into Georgiana Slough was evaluated. The evaluations were conducted in four Phases in 1993/ 94/95/96. While initial work in 1993 (Phase I) looked promising, and the 1994 (Phase II) evaluations demonstrated some success (57% guidance efficiency overall, most effective during daytime and ebb tides), the last 1996 (Phase IV) evaluations resulted in overall guidance efficiencies that were not significantly different from zero. Environmental evaluations during operation of the acoustic barrier in all four years showed little or no unintended effects.

REVIEW OF THE SPRING, REAL-TIME MONITORING PROGRAM IN THE SACRAMENTO-SAN JOAQUIN DELTA

Kevan A.F. Urquhart*[1], K. Fleming[1], and M. Chotkowski[2]

[1]**Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 952025**
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: kurquhar@delta.dfg.ca.gov

[2]**U.S. Bureau of Reclamation, 2800 Cottage Way, Sacramento, CA 95819**

The Bay-Delta Accord called for operational flexibility to "...ensure biological protection... consistent with the Federal and State Endangered Species Acts." It specifically called for the use of real-time monitoring of species as a basis for decisions regarding operational flexibility, and committed to "...aggressively develop more reliable mechanisms for real time monitoring." In 1995, the Interagency Ecological Program (IEP) initiated a 2-month pilot program to satisfy that commitment. It was the first time anyone tried to develop processes to provide biological data on a real time basis. This pilot program was expanded to three months (April through June) and continued to be revised for the next five years (1996-2000).

The IEP's spring, Real-time Monitoring (RTM) Program in the Delta is the collection and quick reporting of multi-species fisheries data, emphasizing three species (splittail, delta smelt and fall-run chinook salmon smolts), from sites within the Delta, during April, May and June. RTM established sampling sites which expanded on existing IEP, United States Fish and Wildlife Service (USFWS) and Department of Fish and Game (DFG) sampling programs. RTM collates fisheries data into a single database, and disseminates it within a 24 to 36 hour period. The data evaluation and dissemination process is hierarchical. First the CALFED/IEP's DAT reviews the results and prepares recommendations to minimize the impact of water operations via weekly or more frequent conference calls. Both RTM and the Water Operations Management Team (WOMT) forward recommendations to the CALFED Operation's Group, where decisions regarding operational flexibility are made.

2000 marks the fifth year of the Delta RTM Program, which has evolved since its genesis, both in the number of locations sampled and the frequency of sampling. We examine both its development and results over the past six years, to determine if the program meets the objectives laid out in the 1994 Accord.

DEVELOPING TOOLS FOR LARGE-SCALE RESTORATION ON THE MERCED RIVER

Jennifer Vick*

Stillwater Sciences, 2532 Durant Avenue Suite 201, Berkeley, CA 94704
Phone: 510-848-8098, Fax: 510-848-8398, e-mail: jen@stillwatersci.com

Hydrologic and geomorphic conditions in the Merced River have been greatly altered by dams, flow diversion, and gold and aggregate mining. The physical effects of flow regulation and mining in the Merced River have been documented by previous studies and include elimination of large floods; large reduction in the magnitude of frequent floods; disconnection of the floodplain from the active channel and conversion of large areas of floodplain to dredger tailings piles; channel incision, narrowing, and simplification; elimination of coarse sediment supply; and creation of large in-channel pits that intercept bedload being transport from upstream. These previous studies, while useful for identifying restoration needs, provide only a snapshot of current conditions in the river. They do not provide insight into mechanistic relationships needed to develop a restoration plan and restoration project designs. Stillwater Sciences and Merced County are currently conducting a multi-phased effort to develop a comprehensive restoration plan for the river. This effort includes a combination of extensive public outreach and scientific studies. The objective of the scientific evaluations is to quantify relationships between flow, sediment transport, channel morphology, and the distribution and quality of in-channel and floodplain habitats. Analyses include assessing riparian vegetation extent and type at the river-wide scale; developing a model that quantifies relationships between riparian vegetation type and inundation frequency at the site-specific scale; and assessing bed mobility thresholds and sediment transport rates at the reach-scale. To support these analyses, Stillwater Sciences has conducted reconnaissance-level and detailed field evaluations and has developed GIS databases and a reach-scale sediment transport model that can be used in gaming to identify the effects of altering coarse sediment supply and/or channel and floodplain cross sections on sediment transport and texture. These models, combined with the results of the field assessments, will be used to identify and design appropriate restoration projects.

SALMON STOCK ORIGIN AS DETERMINED BY OTOLITH GEOCHEMISTRY IN SACRAMENTO AND SAN JOAQUIN WATERSHEDS, CALIFORNIA

Peter K. Weber[*1], B.L. Ingram[2], and I.D. Hutcheon[3]

[1]**501 McCone Hall, Dept. of Geography, University of California, Berkeley, CA 94720**
Phone: 510-642-2381, Fax: 510-642-3370, e-mail: pweber@socrates.berkeley.edu

[2]**Dept. of Geology, University of California, Berkeley, CA 94720**

[3]**Isotope Sciences Division, Lawrence Livermore National Laboratory,**
P.O. Box 808, Livermore, CA 94551

Winter and spring runs of chinook salmon in the Sacramento River are listed under state and federal endangered species legislation. Management practices designed to mitigate for declines in these populations would benefit from additional methods for identifying these stocks. Our work centers on developing geochemical methods for determining the natal origin and out-migration history of juvenile salmon. The geochemical recorder for this work is the salmon otolith, which is a calcium carbonate concretion in the inner ear. Otoliths are particularly useful for this work because they have daily banding (width about 5 to 20 microns) in rearing and out-migrating juvenile salmon. If the chemistry of otolith bands can be related to specific locations or habitats, a chronology of out-migration can be constructed.

Our work has shown that the strontium isotopic composition ($^{87}Sr/^{86}Sr$) of juvenile salmon otoliths is strongly correlated with river water $^{87}Sr/^{86}Sr$. Important salmon spawning rivers within the Sacramento-San Joaquin system have distinct $^{87}Sr/^{86}Sr$ ratios because of systematic differences in the isotopic composition of bedrock. The tributary rivers in the Sacramento River drainage have lower $^{87}Sr/^{86}Sr$ ratios (0.7039 to 0.7066) than the tributary rivers of the San Joaquin River basin (0.7070 to 0.7085), with important exceptions (2 sigma measurement precision about 0.00002). Differences in otolith trace element chemistry can also be related to differences in river water chemistry. Seasonal variation in these geology-based markers is low relative to differences between rivers.

A NEW APPROACH TO PREDICTING THE RISKS POSED BY CONTAMINATED SEDIMENTS

Donald P. Weston* and J. Gunnarsson

Dept. Integrative Biology, University of California, 3060 Valley Life Sciences Bldg., Berkeley, CA 94720-3140, Phone: 510-231-5626, Fax: 510-643-6264, e-mail: dweston@uclink4.berkeley.edu

It is well established that sediment-associated contaminants are bioavailable, but the bioavailable fraction is often a small proportion of the total contaminant chemically quantifiable. In vitro extraction of sediments using the digestive fluid of aquatic organisms has recently been proposed as a means to determine how much sediment-associated contaminant is bioavailable. The technique has many potential applications in sediment risk assessment and ecosystem restoration. Several data sets have shown the digestive fluid extraction assay is capable of predicting the potential for bioaccumulation of contaminants by organisms exposed to the contaminated material. Digestive fluid extraction using fluid from a polychaete was compared to bioaccumulation by a clam (*Macoma nasuta*), one of the traditional means of assessing bioavailability, using sediments from a naval harbor in San Francisco Bay. These sediments were highly contaminated by many trace metals, PAH and PCB. Clams held in these sediments showed bioaccumulation of PAH and PCB, yet little trace metal uptake except for small amounts of Pb and Cd. Digestive fluid extraction results were an excellent predictor of clam bioaccumulation for both the organics and metals, in particular demonstrating that only about 1% of the sediment-bound metal was extractable. Other data sets are presented which assessed the usefulness of the technique in predicting bioaccumulation of mercury, PCB and nonylphenol by amphipods. Overall, there has been a high correlation for both organics and metals in the amount solubilized in polychaete digestive fluid and bioaccumulation by several non-polychaete taxa, suggesting this technique has great cross-phyletic potential is estimating risk from contaminated sediments or how this risk may change due to restoration activities.

A COMPARISON OF PHYTOPLANKTON BLOOM DYNAMICS IN SUISUN, SAN PABLO AND CENTRAL SAN FRANCISCO BAYS

Frances P. Wilkerson*, R.C. Dugdale, V. Hogue, A. Marchi, and A. Lassiter

Romberg Tiburon Center, San Francisco State University, 3152 Paradise Drive, Tiburon, CA 94920-0855, Phone: 415-338-3519, Fax: 415-435-7120, e-mail: fwilkers@sfsu.edu

As part of an EPA-funded project to devise indicators of ecosystem condition, that complements the CALFED Program, monthly cruises (starting October 1999) to Suisun, San Pablo and Central San Francisco Bay have been made to measure lower trophic level processes. In addition, a transect of 6 stations across Central Bay have been sampled monthly from October 1997 to 1999. At each location, conductivity, temperature and depth (CTD), light penetration, nutrients (nitrate, silicate, ammonium and phosphate) were measured. Phytoplankton biomass (as chlorophyll) was measured for the entire phytoplankton community and for cells greater than 5 µm and 10 µm. Phytoplankton species were enumerated using the Utermohl technique. Productivity was evaluated using N-15 labeled nitrate and ammonium uptake and C-13 fixation (fractionated by size class) with samples incubated under natural turbidity and clarified water conditions. The central bay time series data from 1997 to 1999 showed spring blooms of chlorophyll with smaller increases in chlorophyll also in the fall. A spring increase in chlorophyll was also observed in 2000, at all three locations and was then sampled weekly. Data collected during these spring blooms will be described. Among the larger cells *Skeletonema costatum* was the most abundant phytoplankter in the Suisun Bay "bloom" sample. Overall, our comparable data indicates that nutrients decrease in a seaward direction, light penetration increases. Suisun tends to have the lowest total chlorophyll concentrations. When chlorophyll concentrations are high the population is typically dominated by the larger cells (5 µm or 10 µm). The interaction of physical features and human sources of variability with bloom development and productivity will be discussed.

GEOMORPHIC EVOLUTION OF FRESHWATER TIDAL WETLANDS WITHIN BREACHED LEVEE SITES OF THE SACRAMENTO-SAN JOAQUIN DELTA

Philip B. Williams[*1], M.K. Orr[1], and D.J. Reed[2]

[1]**Philip Williams & Associates, 770 Tamalpais Drive, Suite 401, Corte Madera, CA 94925**
Phone: 415-945-0600, Fax: 415-945-0606, e-mail: pbw@pwa-ltd.com

[2]**Department of Geology and Geophysics, University of New Orleans, New Orleans, LA 70148**

This paper presents a conceptual model of the evolution of tidal wetland morphology within breached levee sites in the Sacramento-San Joaquin Delta. The conceptual model was developed as part of a larger study of the ecologic functions of the Delta's breached levee wetlands (Simenstad et al. 2000). We conducted field studies and analysis at 6 breached sites of different ages and 4 natural reference sites to characterize key wetland processes, including open-water sedimentation rates, rates and patterns of emergent marsh expansion, substrate elevation controls on emergent vegetation establishment, rates of marshplain elevation change following vegetation establishment, and channel formation. Core data collected at a large, open water site (406 ha; ~4 m deep) indicates that initial rates of sub-tidal sedimentation (47-51 mm/yr) can be much greater than sea level rise. Long-term rates, however, may be significantly lower since part of the observed sedimentation represents the initial sediment pulse at breaching. Initial large-scale emergent vegetation colonization was observed to occur rapidly (within ~4 yrs), followed by slow (less than 1.5-3 m/yr) lateral expansion to lower elevations. Median elevations of initial pioneer colonization and lateral expansion colonization were +1.0 and -0.3 m MLLW, respectively. The rate of elevation change following vegetation establishment was very slow (~0.8 mm/yr or less relative to sea level) based on comparison of estimated historic marsh elevations with observed current elevations. Marshplain elevations for breached sites were consistently lower than for corresponding natural reference sites. One marshplain that had been vegetated for over 60 years remained 0.48 m below a nearby reference marsh. Because of their lower marshplain elevations, breached sites have larger tidal prisms than reference sites. As expected, tidal channels in breached sites were generally larger than reference site channels.

EVALUATION OF METHODS TO REDUCE OFF SITE MOVEMENT OF DORMANT SPRAY PESTICIDES FROM CALIFORNIA ORCHARDS

Frank G. Zalom[*1], D.E. Hinton[1], B.W. Wilson[1], W.W. Wallender[1], M.N. Oliver[1], B.T. Angermann[1], L.A. Deanovic[1], J.D. Henderson[1], G.H. Oliveira[1], P.P. Osterli[2], W.H. Krueger[2], and I. Werner[1]

[1]**University of California, 1 Shields Ave., Davis, CA 95616**
Phone: 530-752-8350, Fax: 530-752-6004, e-mail: fgzalom@ucdavis.edu
[2]**University of California Cooperative Extension, Modesto and Orland, CA**

Organophosphorous (OP) insecticides, especially diazinon and chlorpyrifos, have been routinely detected in waterways at concentrations exceeding EPA standards coincident with storm events which follow their application to dormant orchards in the Sacramento and San Joaquin River watersheds. Best Management Practices (BMPs) have been identified to mitigate the use of OPs specifically; their use might also help prevent offsite movement of other conventional pesticides as well. Scenarios to study include planting vegetation strips along waterways, creating berms to contain water on site, and maintaining orchard floor vegetation cover. A team of integrated pest management and extension specialists together with hydrologists, chemists and toxicologists are quantitatively evaluating the reduction of off site movement and toxicity of dormant sprays currently focusing on the water soluble, diazinon, and the more hydrophobic, esfenvalerate, pesticides. Data on pest control efficacy, hydrological field modeling, runoff exposure levels and toxicity to test organisms will be presented. Supported in part by CALFED contract #B-81609.

OCEAN DIET CYCLE OF CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) IN THE GULF OF THE FARALLONES

Peter B. Adams*, W.M. Samiere, and C.J. Ryan

National Marine Fisheries Service, 3150 Paradise Dr., Tiburon, CA 94920
Phone: 415-435-3149 ext. 232, Fax: 415-435-3675, e-mail: pete.adams@noaa.gov

Chinook salmon (*Oncorhynchus tshawytscha*) in the Gulf of the Farallones feed in a predictable seasonal diet cycle that is associated with changes in feeding location. The cycle begins in mid-February with salmon feeding nearshore on northern anchovy (*Engraulis mordax*) and Pacific herring (*Clupea harengus*). In April, salmon move offshore to feed on juvenile rockfish (*Sebastes* spp.), and the euphausiid (*Thysanoessa spinfera*). In July, salmon return to the nearshore to feed exclusively on anchovy. The switching from one prey to another is related to the spatial and temporal separation of the different prey complexes. Chinook salmon feed on prey that form large, highly-aggregated concentrations. These concentrations are reproductive adaptations to the ocean current system in which the prey live. The prey of chinook salmon need to aggregate for reproductive reasons, but expose themselves to heavy predation as a result. This diet cycle breaks down during El Niño events when the prey's reproductive behavior is disrupted due to changes in the ocean regime and the prey concentration do not form. Salmon catch drops to historical lows and salmon have lower body weight and suffer loss of condition.

EVOLUTION OF WATER QUALITY IN THE COSUMNES RIVER WATERSHED: ARE THE UPLANDS IMPORTANT?

Dylan S. Ahearn[*1] and R.A. Dahlgren[2]

[1]**University of California at Davis, Department of Land, Air, and Water Resources. 1 Shields Ave., Davis, CA 95616, Phone: 530-752-3073, Fax: 530-752-1552, e-mail: dsahearn@ucdavis.edu**

[2]**University of California at Davis, Department of Land, Air, and Water Resources, 1 Shields Ave., Davis, CA 95616**

Water quality in the Cosumnes River watershed is affected by several factors including climate, geology, soils, vegetation and land-use. Understanding water quality at the large watershed scale is a critical first step for determining whether activities in the upper watershed are likely to have an impact on ecosystem health and restoration efforts in the lower watershed and Bay-Delta. Thus, there is a critical need to understand water quality at the watershed scale and to determine the biogeochemical processes regulating water chemistry. The primary objectives of this research are to examine patterns in water quality within the Cosumnes River watershed (2745 sq. km) and to determine the contribution of natural and anthropogenic processes in regulating water quality. Water samples were collected biweekly for two years from up to 28 sites (fewer during maximum snowpack) and daily during storm events from 7 sites along the main stem. Data indicate that the majority of the nutrients (nitrogen & phosphorus) and suspended sediments originates from the lower portion of the watershed below the Michigan Bar gauging station. Nutrient loadings in the lower watershed are strongly affected by a few point sources (e.g., wastewater treatment facilities) and from nonpoint sources related to urban areas and agriculture. Nutrient concentrations show a distinct seasonal pattern with highest concentrations during the early portion of the water year (fall-winter) and decreasing concentrations during the spring and summer. The majority of nutrient and sediment transport occurs during storm events with only minor transport occurring during baseflow conditions. Warmer water temperatures and longer hydrologic residence times during the summer period of low flow are important factors responsible for attenuating nutrient concentrations in stream water. Ongoing research is examining linkages between water quality and food web dynamics at the watershed scale.

BIOAVAILABILITY OF SELENIUM AFTER BACTERIAL REDUCTION: IMPLICATIONS FOR AGRICULTURAL DRAIN WATER TREATMENT

Erin L. Amweg* and D.P.Weston

Department of Integrative Biology, University of California, 3060 VLSB, Berkeley, CA 94720
Phone: 510-642-8690, Fax: 510-643-6264, e-mail: eamweg@socrates.berkeley.edu

The fertile agricultural soils of the San Joaquin Drainage Basin, CA contain naturally high levels of selenium which leaches into irrigation water and is released to surface waters. Recent legislation mandates a sharp reduction in selenium loading to protect downstream wildlife from the teratogenic effects of exposure to high selenium levels. A prototype Algal-Bacterial Selenium Removal system in place in the Panoche Drainage District, CA currently removes 40% of total selenium in the effluent after bacterial reduction and precipitation. Despite the reduction in total Se, invertebrates including chironomids and corixids, and algae living in the treated water of the removal system contain 2-4 times the selenium burden and 2 to 10 times higher BCF as invertebrates and algae living in the untreated water of the system. These results are supported by laboratory algal bioaccumulation tests and suggest that the remaining selenium is converted to much more bioavailable form, presumably organoselenium compounds. Planned system improvements to address this problem include installation of a dissolved air flotation (DAF) step to capture particulates containing selenium. Assessment of DAF success is addressed by mesocosm studies and implications for large-scale use of the system as also discussed.

PESTICIDE IMPACTS ON GENE POOLS OF CALIFORNIA NATIVE FISH: A COMBINED LABORATORY AND FIELD APPROACH

Susan L. Anderson[1], J. Andrew Whitehead[*1], B.P. May[2], K. Kuivila[3], B.W. Wilson[2], and J.L. Orlando[3]

[1]**University of California-Davis, Bodega Marine Laboratory, Bodega Bay, CA 94923**
Phone: 707-875-1971, Fax: 707-875-2089, e-mail: awhitehead@ucdavis.edu

[2]**University of California, Davis, Dept. of Animal Science, Davis, CA**

[3]**U.S. Geological Survey, Sacramento, CA**

Widespread agricultural pesticide application has been demonstrated to contaminate surface waters of the Sacramento and San Joaquin watersheds at concentrations toxic to test invertebrates. However, long term effects of contamination on resident fish species have not been examined. Contaminants can alter the survival, recruitment, reproductive behavior, and DNA integrity of individuals, which may, in turn, perturb gene pools over time. The goal of this project is to test whether long-term exposure to pesticide contamination causes change in gene pools of a California native fish, Sacramento sucker (*Catostomus occidentalis*). This work will result in the development of nested suites of indicators of pesticide exposure and effects. We focus on organophosphate pesticides in the Central Valley of California due to widespread aquatic contamination and their long-term use. We coupled Department of Pesticide Regulation Pesticide Use Database information with GIS mapping and water chemistry monitoring reports to characterize historical pesticide contamination patterns. Results of this integrated analysis were used to rank and select sampling sites. Field and laboratory experiments, using acetylcholinesterase activity and DNA strand breakage, were employed to characterize proximate effects of pesticide exposure on native fish. DNA strand break data indicate significantly elevated damage from the San Joaquin River (38.8% and 28.4% DNA strand breakage in field and lab exposures, respectively) compared to a nearby reference site (15.4% and 8.7% in field and lab exposures, respectively). These and other data indicate that contaminants other than pesticides could be having deleterious effects on species in the San Joaquin River. We have collected over 700 Sacramento sucker fin clips from 9 reference and 5 potentially impacted populations spanning 7 river systems. We are employing microsatellite and amplified fragment length polymorphism (AFLP) technologies to examine long-term effects of pesticide exposure on population gene pools. (Supported by EPA Star Grant 98-NCERQA-D1).

PESTICIDE RUNOFF—FILLING THE DATA GAP

Till E. Angermann[*1], W.W. Wallender[2], J.D. Henderson[2], G.H. Oliveira[2], B.W. Wilson[2], I. Werner[2], L.A. Deanovic[2], D.E. Hinton[2], P. Osterli[3], W. Krueger[4], M. Oliver[3], and F. Zalom[2]

[1]**Dept. of Land, Air and Water Resources, University of California, 1 Shields Ave., Davis, CA 95616 Phone: 530-752-7415, Fax: 530-752-5262, e-mail: teangermann@ucdavis.edu**

[2]**University of California, 1 Shields Ave., Davis, CA 95616**

[3]**UC Cooperative Extension, 3800 Cornucopia Way, Suite A Modesto, CA 95358**

[4]**UC Cooperative Extension, 821 E. South Street, P.O. Box 697, Orland, CA 95963-0697**

California lakes and rivers receive pesticide residue from agricultural fields and orchards via surface water runoff. Of particular concern are organophosphate insecticides, used as dormant sprays on orchards, that are ending up in open water bodies at toxic levels. Proper identification of their source areas is difficult and there is a lack of orchard specific field data that can be used to determine its potential to contribute dormant spray residue to open water bodies.

We developed a methodology to describe and predict an orchards' hydrologic response to precipitation by limiting ourselves to taking one measurement of total runoff at the end of an event in tandem with some readily obtained orchard specific properties. We use a meso-scale plot-retention tank technique in the field to generate data to support a kinematic wave model (Joyce and Wallender) which calculates runoff hydrographs via an inverse optimization process invoking the Green and Ampt infiltration model. A calibrated rainfall simulator is used in situ to gain independence from natural rain events.

High-resolution time series measurements of Diazinon concentration in the runoff during simulated precipitation events on a variety of ground treatments have consistently shown a decrease in concentration over time resembling that of an exponential decay function.

The shape of the hydrographs in conjunction with the temporal distribution of the concentration graphs give insight into the temporal character of residue mass contribution to the downstream environment.

We will present detailed information on the hydrologic responses of resident vegetation (grass-clover mix), perennial sod mix, non-tillage clover and bare ground, and on Diazinon mass fluxes generated in a French Prune orchard in Artois, Glenn County. Furthermore, current runoff experiments conducted in an apricot orchard in Davis, Yolo County, will be reported on.

DEVELOPMENT OF A BASELINE MONITORING PLAN FOR THE ECOSYSTEM RESTORATION PROGRAM: TERRESTRIAL AND AMPHIBIOUS MONITORING RECOMMENDATIONS

Andrea J. Atkinson*, C.M. Marn, and P.A. Stine

Western Ecological Research Center, U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA 95819-6129, Phone: 916-278-3261, Fax: 916-278-3199, e-mail: andrea_atkinson@usgs.gov

The CALFED San Francisco Bay-Delta Program is one of the largest, most ambitious, and most complex, multiple-objective resource management efforts in the world whose purpose is to "restore ecosystem health and improve water management for beneficial uses of the Bay-Delta System." CALFED needs information on status and trends in ecosystem health, the effectiveness of CALFED actions, and to assist with decision-making. We describe the design process for the terrestrial and amphibious baseline monitoring for the Ecosystem Restoration Program (ERP) and provide examples from the initial list of recommendations.

Developing a comprehensive environmental monitoring program that will effectively assist management decision-making requires an organized, systematic approach. We adopted the following steps, as part of an iterative process: 1) determine monitoring program objectives; 2) compile information about existing monitoring programs; 3) identify relevant time-scales and geographic organization; 4) develop a management-oriented conceptual framework linking resources of concern with their associated natural and anthropogenic pressures and management actions; 5) construct conceptual models of hypothesized relationships in the system at various scales of focus; 6) identify candidate monitoring elements; 7) address sampling design and methodologies; 8) determine data management, assessment and reporting mechanisms; and 9) ensure links to decision-making.

We focused on steps 1-6 to develop initial, "straw-dog," management-oriented conceptual models and lists of monitoring recommendations. These efforts drew heavily from conceptual models and monitoring recommendations in the CMARP technical papers, ERP white paper efforts, and others. These recommendations were initially reviewed and refined through a series of workshops. A report will be available in fall 2000. We fully expect that this list of monitoring elements will be modified as they are subjected to wider review, as subsequent steps of the design process are completed (i.e. steps 7-9), and as the CALFED programs are refined and implemented.

PURPLE LOOSESTRIFE: A THREAT TO CALIFORNIA'S WATERWAYS

Carri B. Benefield* and C. Gallagher

California Department of Food and Agriculture, 1220 N Street, Room A-357, Sacramento, CA 95814
Phone: 916-654-0768, Fax: 916-653-2403, e-mail: cbenefield@cdfa.ca.gov

Purple loosestrife is a showy ornamental that has escaped home gardens and nurseries and moved extensively throughout the wetlands of the United States causing immense ecological destruction. Loosestrife is listed by the CDFA as a "B" rated noxious weed and as a "species with potential to spread explosively" by the California Exotic Pest Plant Council. Based on historic records, the distribution of purple loosestrife is currently in multiple, mostly small and scattered populations, in the Sacramento-San Joaquin Delta system and nearby hydrological units. However, infestations of purple loosestrife often follow a pattern of establishment, maintenance at low numbers, and then dramatic population increase when conditions are optimal. Purple loosestrife, which spreads primarily by copious production of seed the size of ground-pepper, threatens to become established and forms dense stands that crowd out native wetland vegetation and associated wildlife, thus threatening the overall biodiversity of aquatic, wetland, and riparian areas. The complex interface between farm land and water in the Bay-Delta estuary also provides rich and varied habitat for wildlife, particularly waterfowl. The displacement of valued flora and fauna and the diminishment of critical fish and wildlife habitats has been well documented throughout the United States. Primary program objectives include: (1) a broad education and training campaign, (2) extensive surveying and mapping, (3) a collaborative assessment meeting of cooperators to develop site specific adaptive management plans, resulting in (4) comprehensive local management, control, and eradication efforts, and (5) monitoring. The project will be an extensive collaborative effort with: CDFA Integrated Pest Control Branch District Biologists, County Agricultural Commissioners, local Weed Management Areas, CA Department of Boating and Waterways, the CA Department of Fish and Game, U.S. Fish and Wildlife Service, USDA-ARS Resource Conservation Districts, and local watershed groups, amongst others.

IDENTIFYING FACTORS INFLUENCING CONDITION AND GROWTH OF DELTA SMELT IN THE SAN FRANCISCO ESTUARY

William A. Bennett[1,2], S.J. Teh[*3], S.L. Anderson[2], J.A. Hobbs[2,4], D.P. Martasian[2], K.R. Marlow[2], F.C. Teh[3], and J.E. Machula[2]

[1]**John Muir Institute of the Environment, University of California, 1 Shields Ave., Davis, CA 95616**

[2]**Bodega Marine Laboratory, University of California, Davis, Bodega Bay, CA**

[3]**Department of Anatomy, Cell Biology, and Physiology, School of Veterinary Medicine, 1321 Haring Hall, University of California, 1 Shields Ave., Davis, CA 95616**

[4]**Department of Wildlife, Fish, and Conservation Biology, University of California, 1 Shields Ave., Davis, CA 95616**

Considerable speculation clouds understanding of the relative importance of factors regulating the abundance of the threatened delta smelt, *Hypomesus transpacificus*, in the San Francisco Estuary. We have been developing an integrated interdisciplinary program for distinguishing the relative importance of contaminant exposure from other factors (e.g. food limitation) on the growth, condition, and mortality of delta smelt. In 1999, we obtained delta smelt larvae, juveniles and adults from a variety of seasons and locations in cooperation with Interagency Ecological Program monitoring programs. Individual specimens are evaluated for growth rate and pattern from otoliths, histopathological condition of tissues and organs, as well as genotoxic responses determined by degree of DNA strand breakage. Currently, evaluation of 125 otoliths from juvenile smelt indicates overall growth rate through averaged 0.39 mm per day. Semi-quantitative histopathological analysis of 10 characteristics from 109 specimens indicates 10% of livers exhibit abnormalities consistent with a contaminant etiology. These features include cholangiocarcinoma, preneoplasmic foci, hepatic necrosis, and megalocytosis, from specimens collected from Montezuma Slough, Grizzly Bay, and Ryer Island stations. In addition, copepods were rare in specimens collected from the Grizzly Bay and Ryer Island stations. Comparison of growth between “healthy” and “impaired” specimens indicates average deposition rate of otolith daily increments of impaired individuals was significantly lower than for healthy specimens collected from the same location. DNA strandbreaks were measured by an electrophoretic assay (the Comet Assay) in which damaged DNA migrates away from the nucleus. The percentage of damaged DNA in nuclei of red blood cells ranged from 19 to 69% for 13 blood samples collected during July. The highest values (55%, 65%, and 69%) were also observed in Montezuma Slough, Grizzly Bay, and Ryer Island stations. Overall, our integrated approach provides a promising suite of tools for evaluating the relative importance of factors regulating the delta smelt population.

MODELING TEMPORAL VARIABILITY AND SPATIAL COMPLEXITY IN THE COSUMNES-MOKELUMNE RIVERS AND THE NORTH DELTA

Stephen H. Blake* and S.G. Schladow

Civil and Environmental Engineering, University of California, 1 Shields Ave., Davis, CA 95616
Phone: 530-752-6932, e-mail: shblake@ucdavis.edu

Previous hydraulic studies of the Cosumnes River have focused on the purely riverine characteristics of the middle basin, and only permitted consideration of steady flow. As the only remaining large Delta tributary with a natural flood hydrograph, the unsteady nature of the river is unique. Understanding the unsteadiness of the river system is an important component of ecological restoration, flood mitigation, and geomorphological processes in the Delta region. In this paper we describe and apply a dynamic, hydraulic numerical model of the North Delta. The model is based on MIKE-11. It includes all the streams and sloughs that comprise the North Delta. The model boundaries are the San Joaquin River to the south, the flow measuring stations on the Sacramento, and the foothill gages on the Cosumnes, Mokelumne and Dry Creek. Though essentially one-dimensional, the model can be configured to describe the interactions between the channels and their floodplains, and the floodplain restrictions caused by levees and weirs, roadways, railroads, and bridges. This provides a dynamic tool for the simulation of riverine and Delta processes, and the potential hydraulic impacts of selected modifications and restoration strategies.

The hydrology of the last five flood seasons has been selected for analysis. This period, from 1996-2000, provides a wide range in peak and total volume flows, and represents a nearly inclusive set of boundary condition data. Model predictions in the vicinity of the Cosumnes River Preserve are the focus of this study, with an emphasis on magnitude, duration and frequency of flood flows on the floodplain. This information will be used to inform and guide on-going assessments of fish use of flooded habitat in the area. This model will be expanded to assess the hydraulic impacts of planned or proposed restoration activities throughout the North Delta, with an emphasis on the McCormack-Williamson Tract.

MERCURY CONTAMINATED HYDRAULIC MINING DEBRIS IN SAN FRANCISCO BAY SEDIMENTS

Robin M Bouse*, S. Luoma, C. Fuller, M. Hornberger, B. Jaffe, and R. Smith

U. S. Geological Survey, 345 Middlefield Rd., MS-465, Menlo Park, CA 94025
Phone: 650-329-4448, e-mail: rmbouse@usgs.gov

A multi-isotopic approach in conjunction with age-dating and elemental concentrations best constrains the possible sources of contaminated sediment in San Francisco Bay. Such studies on cores from the Bay suggest that historic Hg contamination associated with hydraulic gold mining in the Sierra-Nevada (1852-1884) persists in Bay sediment today. Indicators of hydraulic mining debris reflect the geochemical and mineralogical characteristics of sediments in abandoned hydraulic gold mines in the Sierras. Indicators include more negative (epsilon)Nd, increased 87Sr/86Sr, 206Pb/204Pb,208Pb/207Pb, increased Pb, REE, U, Th, and Hg concentrations, decreased Ni, Ca, Sr concentrations, and increased quartz/plagioclase. Sparse shell material, lack of bioturbation, decreased TOC, and a red brown color (in contrast to a gray color in the rest of the core) also characterize the hydraulic mining layer in the cores. In core layers that contain hydraulic mining debris, the Hg concentrations average approximately 0.4 micrograms/gram. Mercury in the hydraulic mining layer was introduced in its elemental form and thus could be readily converted to methyl mercury. Historical bathymetry studies suggest that in erosional areas and in marshes and islands built by the hydraulic mining debris, this bioavailable Hg could be at or near the surface. Hydraulic mining debris containing Hg should be considered in the restoration of wetlands. It is estimated that 400 million m3 of sediment was deposited in the North Bay between 1856 and 1887. Approximately 400 tonnes of Hg came in with this sediment. A conservative estimate of the amount of Hg lost in mine tailins is 10,000 tonnes. Thus, less than 5% of the Hg used in the gold mining ended up in the North Bay. The rest of the Hg likely remains in the Delta, rivers, abandoned mines, Sierra-Nevadan streams, and/or trapped behind dams. Mercury-laden sediments should be considered in the plans to remove dams.

STUDIES INTO RESTORATION AND THE EFFECTS ON FLOOD CONVEYANCE CAPACITY OF THE NAPA REIVER USING HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELING

Chris Bowles

Philip Williams & Associates, 770 Tamalpais Drive, Suite 401, Corte Madera, CA 94925
Phone: 415-945-0600, Fax: 415-945-0606, e-mail: cbowles@pwa-ltd.com

The Napa River drains 426 square miles of the California Coast Ranges in Napa and Solano Counties, California. Historical repetitive flooding has occurred in this watershed, with particularly damaging floods occurring recently in 1986, 1995 and 1997. As a result, the Napa Community Coalition was formed to work alongside the Corps of Engineers (COE) to develop a community-based, environmentally friendly flood damage reduction plan for the Napa River through the City of Napa (Napa River Flood Protection Project, NRFPP). Philip Williams and Associates (PWA) has been extensively involved since 1991 by providing technical assistance to both the Community Coalition and the COE. The project is designed to provide 100-year flood protection for the City of Napa combined with restoration of historic tidal marshlands and alluvial floodplains. This strategy, termed the "Living River Strategy" by the Community Coalition, is considered a national model for flood protection and river restoration by the COE.

PWA used geomorphic principles to develop a channel design for the Napa River from just upstream of the City of Napa, through the City, to approximately 11 km downstream. The project reach is in the tidally influenced zone and therefore the design considered both tidal and fluvial channel forming processes. Sedimentation issues are extremely important but are frequently overlooked in flood conveyance capacity studies. PWA constructed a complex sediment transport model of this reach. Lateral variations in sediment transport, erosion and deposition were accounted for through the use of a one-dimensional looped network model (MIKE 11) capable of simulating flow in the main channel, marshplain terrace and floodplain terrace as separate flow paths. Non-cohesive and cohesive sediments were simulated and, once validated, the model was used to assess the performance of the Geomorphic Channel Design, to identify areas of excessive deposition or erosion. This poster will focus on these sedimentation issues.

In addition, PWA used the hydrodynamic model simulation results and the GIS package, ArcView to develop Digital Elevation Models (DEMs) and Flood Inundation Maps (FIMs) for both the existing and project conditions. PWA also developed a conceptual plan for enhancement of the alluvial floodplains and tidal marshlands of the Upper Napa River Estuary. This plan included restoration of over 1000 acres of tidal wetlands, freshwater wetlands, alluvial floodplains and upland areas. PWA developed GIS maps of the enhancement areas, provided enhancement recommendations and projected future conditions based on the recommendations.

METAL TRENDS AND EFFECTS IN *POTAMOCORBULA AMURENSIS* IN NORTH SAN FRANCISCO BAY

Cynthia L. Brown*, S.N. Luoma, F. Parchaso, and J.K. Thompson

U.S. Geological Survey, MS 465, 345 Middlefield Rd., Menlo Park, CA 94025
Phone: 650-329-4477, Fax: 650-329-4545, e-mail: clbrown@usgs.gov

Long-term, multi-disciplined field sampling was used to assess the fate and effects of trace metals in northern San Francisco Bay. Bioaccumulation in the bivalve Potamocorbula amurensis was measured at near-monthly intervals from 1990 - present. Three accumulation patterns were detected. 1) Cr, Ni, and V tissue concentrations were related to the combined influences of riverine inputs, resuspension, and local industrial inputs. Seasonally, the highest tissue concentrations of Cr, Ni, and V coincided with high river inflows. Annual mean concentrations were also higher in years of high precipitation and river inflow. This suggests that trends in metals like Cr (e.g. the Regional Monitoring Program) may reflect trends in precipitation and river inflows more than trends in contamination. 2) Cadmium and Ag tissue concentrations could not be clearly related to any obvious source. However, both elements were linked to episodes of adverse effects on bivalves. Cadmium uptake was linked inversely to condition index, glycogen content, reproductive activity, and histopathology. A pulse of Ag contamination in the early 1990s in mid-Suisun Bay was linked inversely to condition index and may have contributed to the reduction of reproductive activity in P. amurensis. 3) Cu and Zn appear to be biologically regulated by P. amurensis, which provides an important control on tissue concentrations. This was evidenced by the absence of persistent spatial or temporal trends in the tissue concentrations of Cu or Zn, and the correlation of Cu and Zn tissue concentrations with the weight of the clam. Thus metal exposure of organisms in Suisun Bay is complicated by different sources and different seasonal dynamics among the metals. Some metals are linked to adverse effects on important biological processes, while biological processes appear to regulate exposures to other metals. Metal contamination of Suisun Bay should be an important consideration in evaluating restoration of that ecosystem.

PERMEABILITY AND NEAR-SURFACE WATER CHEMISTRY OF A SALMON SPAWNING GRAVEL BAR IN THE AMERICAN RIVER, SACRAMENTO

Noel J. Bush[*1] and T.C. Horner[2]

[1]**U.S. Geological Survey, Placer Hall, 6000 J St., Sacramento, CA 95819**
Phone: 916-278-5635, e-mail: noelbush@usgs.gov

[2]**Geology Department, California State University, 6000 J St., Sacramento, CA 95819**

Assessment of in-stream conditions is a critical component of restoration projects that alter fish habitat. This study examines physical and geochemical factors that influence salmon spawning site selection at four localities along a partially submerged 0.25 mile gravel bar in the American River. Historic data show that two of the localities are consistently used as spawning sites, one locality is unlikely to be used for spawning, and one is an occasional spawning site.

Physical parameters were compared between river water and the underlying saturated gravel. Hydraulic head measurements showed simultaneous gaining and losing conditions along the composite longitudinal gravel bar, and spawning occurred in both gaining and losing areas. Field and lab measurements were also used to compare river water chemistry to gravel pore water geochemistry. Temperature, pH, dissolved oxygen, turbidity and conductivity were recorded for surface water, then a drive point piezometer was pounded to 1 ft and 2 ft depths to measure field parameters and collect shallow pore water samples. Samples were preserved for later analysis of Ca, Na, K, Mg and Fe by atomic absorption.

Results indicate that dissolved oxygen content drops from 6.2 mg/l (river values) to less than 3.4 mg/l at 1 ft depth below the stream bed surface. Conductivity, pH, turbidity and metal content are less variable and correlate with gaining or losing conditions. In general, losing conditions produce pore water that is similar to river water. Gaining conditions result in pore water that is more isolated from the surface, with reduction in pH and slight but measurable mobilization of metals. None of these individual parameters correlate with salmon spawning sites, suggesting that spawning site selection is a complex interplay of more than one variable. Evaluation of similar sites is planned to confirm or refute the findings of the initial study.

METAL EXPOSURE TO A BENTHIC MACROINVERTEBRATE RELATED TO MINE DRAINAGE IN THE UPPER SACRAMENTO RIVER

Daniel J. Cain[*1], J.L. Carter[1], S.V. Fend[1], S.N. Luoma[1], C.N. Alpers[2], and H.E. Taylor[3]

[1]**U.S.Geological Survey, MS465, 345 Middlefield Rd., Menlo Park, CA 94025**
Phone: 650-329-4478, Fax: 650-329-4545, e-mail: djcain@usgs.gov

[2]**U.S. Geological Survey, 6000 J. St., Sacramento, CA 95819-6129**

[3]**U.S. Geological Survey, 3215 Marine St., Boulder, CO 80303**

A biomonitoring technique was employed to complement studies of metal transport in the Sacramento River. The biological availability of metals in the upper Sacramento River was of special concern because this area includes spawning ground for several species of salmonids. Metals (Al, Cd, Cu, Fe, Hg, Pb, and Zn) were determined in a resident macroinvertebrate, Hydropsyche californica (Insecta: *Trichoptera*), and streambed sediments (<62 µm) to assess metal contamination within a 111 km section of the river between the cities of Redding and Tehama. Metals in *H. californica* also were interpreted to be broadly indicative of metal exposure to insectivorous fish such as juvenile salmonids. Total Hg was determined in the whole body of the insect, whereas Al, Cd, Cu, Fe, Pb, and Zn were also separated into operationally defined cytosolic (used as an indicator of exposure to bioavailable metal) and particulate fractions. Total concentrations of Cd, Cu, Hg, Pb, and Zn in sediments were consistent with documented upstream sources of acid mine drainage. Cadmium, Cu, and Pb distribution patterns in *H. californica* also were consistent with inputs from these sources, but Hg and Zn were not. Concentrations in *H. californica* indicated that bioavailable Cd, Cu, Pb, and Zn were transported at least 120 km downstream of the mine sources. Zinc in *H. californica* was elevated, but unlike sediments, did not decrease downstream. Mercury in *H. californica* was not elevated. Hazards posed by metal enrichments in lower trophic organisms such as Hydropsyche are difficult to evaluate. However, the highest Cd concentrations near Redding (2.16 $\mu g \cdot g^{-1}$ in the whole body and 1.27 $\mu g \cdot g^{-1}$ in the cytosol) were comparable to concentrations in Hydropsyche from the Clark Fork River in Montana, where metal exposure has been associated with effects on benthic invertebrates and resident trout.

THE MCCORMICK/WILLIAMSON TRACT RESTORATION

Valerie R. Calegari* and K.E. Whitener

The Nature Conservancy, 13501 Franklin Blvd., Galt, CA 95632
Phone: 916-683-1703, Fax: 916-683-1702, e-mail: vcalegari@cosumnes.org

In 1999, The Nature Conservancy, using CALFED funding, purchased the McCormick/ Williamson (M/W) Tract. The M/W Tract is located in the primary Delta region along the lower Mokelumne River and encompasses 1,634 acres of farmland and 8.6 levee miles of riparian habitats. The property is significant to CALFED's goals and objectives because of the potential ecosystem benefits that could be realized through the restoration of the property to freshwater tidal marsh and because of its key role in North Delta corridor hydrology. Due to the small ratio of farmable acreage to miles of levee, farming had been marginally profitable for the previous landowner making it a desirable location for restoration and the implementation of flood control measures. Short-term plans include a 200-acre pilot tidal wetland project, exotic tree removal, wildlife friendly levee restoration, and cooperation in the long-term North Delta flood abatement planning process. The pilot tidal wetland project will address many of the uncertainties surrounding restoration of tidal wetlands in the Delta including questions concerning sediment capture in subsided islands and methylmercury production. Future restoration plans, including the conversion of the entire tract to tidal marsh habitat, will depend upon modeling and research efforts currently underway by D.W.R. and U.C. Davis, as well as the continued collaboration with north Delta stakeholders.

THE IMPORTANCE OF THE SACRAMENTO-SAN JOAQUIN ESTUARY AS A NURSERY AREA FOR CHINOOK SALMON

Thomas C.Cannon*

Foster Wheeler Environmental Corp., 3947 Lennane Drive, Sacramento, CA 95834
Phone: 916-928-4804, Fax: 916-928-0594, e-mail: tcannon@fwenc.com

For chinook salmon, estuaries also are an important nursery area where young may spend from weeks to months growing through critical early stages before migrating to the ocean. The period of estuarine residence and the mechanisms by which they reach the estuary may be critical elements in their overall survival. I looked at the various IEP data bases for information on use and timing of entering and leaving the estuary by young chinook salmon. Salmon fry enter Central San Francisco Bay only in very wet years (e.g., 1982, 1983, and 1986) in winter (usually February and March). Fry enter the North Bays and Delta in most wet years and in some dry years with winter flow pulses. Even in the critical year 1992, fry reached the Delta in winter on the Sacramento River, but did not on the San Joaquin River side of the Delta. Flows necessary to get young salmon downstream into the estuary in winter are in the range of 40,000-60,000 cfs in the Sacramento River and as high as 20,000-40,000 cfs in the San Joaquin River. Young and yearling salmon remain through the summer in cool waters of the Central and North Bays, but are rare in the warm waters of the Delta after waters warm to about 70°F in spring of dry years and early summer of wet years.

CENTRAL VALLEY FLOODPLAIN STRANDING

Thomas C.Cannon[*1] **and W. Shaul**[2]

[1]**Foster Wheeler Environmental Corp., 3947 Lennane Drive, Suite 200, Sacramento, CA 95834**
Phone: 916-928-4804, Fax: 916-928-0594, e-mail: tcannon@fwenc.com

[2]**Jones & Stokes Associates, 2600 V St., Sacramento, CA**

Lower river floodplains in the Central Valley are confined by flood control levees that have led to altered channel configurations, modified habitats, and stranding of salmon and steelhead. Federal, state, and local levees confine nearly all the lower portions of Central Valley river channels. Levees and bank protection confine channels and restrict flood flows to a narrow floodplain that leads to unnatural river and floodplain configurations and unnatural habitat that causes stranding. The problems are exacerbated by remnant sediments from historic placer mining that have washed downstream into river floodplains over the past century and have built up in and along the river channel on high terraces on the riverside of the levees. Gravel mining and levee construction borrow pits also have contributed to the problem. Borrow pits are often located next to the levees within the higher terraces. Stranding of juvenile salmon and steelhead in floodplains has been identified by CALFED as a stressor potentially threatening Central Valley populations. Stranding is generally thought to be a wet year phenomenon and thus not a primary concern for restoration programs. While it is true that flooding is more extensive in wet years, stranding habitats are flooded during smaller winter storm events in drier years. Stranding may be even worse in dry and normal years when fish have fewer opportunities to escape stranding habitats during later winter and spring storms that are more typical of wet years. Stranding in floodplain habitats is a stressor that is closely tied to predation problems and floodplain rearing. Floodplain rearing provides for improved growth and survival opportunities important to the populations, but can also lead to higher predation and stranding. Potential improvements to floodplain habitat offer exceptional opportunities to improve survival, smolt production, and escapement, and help toward population recovery.

CONSIDERATIONS FOR THE DEVELOPMENT OF BIOMONITORING IN SAN FRANCISCO BAY AREA STREAMS

James L. Carter*, S.V. Fend, A.M. Evans, and L.R. Gass

U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025
Phone: 650-329-4439, Fax: 650-329-4463, e-mail: jlcarter@usgs.gov

Urban environmental settings pose unique challenges for developing biomonitoring methods for lotic systems. Biomonitoring methods are rarely designed to specifically address the environmental conditions and biomonitoring objectives unique to urban settings. In contrast, our research in the Santa Clara Valley is designed to systematically develop cost efficient, regionally specific biomonitoring methods that can be used in the San Francisco Bay area and other urban centers. Our approach uses a spatially dense, systematic site selection process that can be used to identify within- and among-stream natural and anthropogenic gradients that potentially influence the distribution of lotic macroinvertebrates. Each of 85 sites was sampled for macroinvertebrates, nutrients, dissolved trace metals, and channel morphology. Land cover and various land cover buffer sizes at each site were obtained from the nationally consistent 30 m Multi-resolution Land Cover (MRLC) data. A variety of methods, ranging from low to high effort, were used for field collecting and laboratory processing of benthic macroinvertebrates. The methods were tested for their ability to differentiate among levels of stressors related to the urban environment. Over 300 taxa were identified from a single sampling of 85 sites in May, 1997. Several combinations of collecting and processing methods differentiated levels of urban influence, based on calculations of both richness- and composition-based metrics. MRLC data were highly correlated to an ordinal index of urban influence constructed from on-site estimates of temperature, turbidity, substratum, channel, and riparian condition. Within-stream longitudinal patterns in macroinvertebrate community composition were always disrupted below impoundments. By partitioning spatial patterns of invertebrate assemblages into groups representing different portions of the longitudinal continuum, more realistic biological criteria for characterizing water quality conditions can be established.

PRIMARY PRODUCTION: A KEY TO THE STATUS OF AQUATIC ECOSYSTEMS

Brian E. Cole* and J. Cloern

U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025
Phone: 650-329-4593, Fax: 650-329-4463, e-mail: becole@usgs.gov

Primary production is the synthesis of new plant matter (biomass) through photosynthesis. Ecosystems like the San Francisco Bay - Delta, are highly productive. Part of this productivity is supported by primary production of the phytoplankton, the food resource for the animals that live in Bay - Delta waters. The capacity of ecosystems to sustain animal populations is set, in part, by the rate phytoplankton produce new plant biomass as a food resource for the animals. What is the rate of primary productivity in San Francisco Bay?

The rate of primary production differs for different areas of San Francisco Bay due to variations in growth resources (nutrients and light), temperature, and possibly pollutants. In South Bay, primary production varies seasonally between 70 and 1,500 mg carbon m-2 d-1 with highest rates in spring. Productivity also varies seasonally in other areas of the Bay, although the timing of minimum and maximum rates differs. Total annual primary production ranges from 3,100 tons of carbon in Suisun Bay to 64,000 tons of carbon in South Bay. Primary production in North Bay is low relative to the rates reported for many estuaries. These low rates result from of high rates of consumption of phytoplankton biomass through grazing by benthic animals and highly turbid waters that limit the penetration of light thereby minimizing the depths where photosynthesis takes place.

Primary production is a fundamental indicator of the status of San Francisco Bay. This is a highly dynamic process that varies spatially as well as seasonally. Therefore, measurement programs to characterize the state of the Bay - Delta should be designed to capture these elements of spatial and temporal variability in production. Programs to monitor primary production can help define the capacity of the system to provide food for the animals in the Bay - Delta.

DISSOLVED ORGANIC CARBON IN THE YOLO BYPASS DURING WINTER AND SPRING 1998 AND 2000

Marisa H. Cox*[1], L.E. Schemel[1], W. Batham[2], and R. Kurth[2]

[1]**U.S. Geological Survey, 345 Middlefield Road, MS439, Menlo Park, CA 94025**
Phone: 650-329-4345, Fax: 650-329-4327, e-mail: mhcox@usgs.gov

[2]**California Department of Water Resources, 3251 S Street, Sacramento, CA 95816**

The Yolo Bypass provides shallow water habitat for native and endangered species. Water quality in the Yolo Bypass varies greatly during winter and spring primarily due to flooding from weirs along the Sacramento River and discharge from west-side streams. Dissolved organic carbon (DOC) was measured along the perennial channel (Toe Drain) of the Yolo Bypass in 1998 and 2000 and in the west-side streams in 2000. When the Sacramento River water inundated the Bypass, DOC concentration decreased during the flooding period in both 1998 and 2000. The DOC concentration increased when the flow from the Sacramento River decreased and the Bypass began to drain. UV absorption normalized to DOC concentration was measured in the 2000 study. Higher UV absorption indicates more-complex aromatic compounds that are less likely to be incorporated into the food chain by microbial processes. UV absorption of the DOC was high during the flooding period, but decreased when the Bypass was draining and the west-side streams became the major source of freshwater. DOC from the Yolo Bypass is a potential source of energy for organisms within the Yolo Bypass as well as downstream because the Bypass discharges into the western Delta and San Francisco Bay.

MERCURY, TIDAL WETLANDS, AND CALFED

Jay A. Davis*[1], D. Yee[1], J.N. Collins[1], S. Schwarzbach[2], and S.N. Luoma[3]

[1]**San Francisco Estuary Institute, 1325 South 46th St., Richmond, CA**
Phone: 510-231-9539, Fax: 510-231-9414, e-mail: jay@sfei.org

[2]**U.S. Fish and Wildlife Service, Sacramento, CA**

[3]**U.S. Geological Survey, Menlo Park, CA**

Tidal wetland restoration and other CALFED restoration actions will alter many processes that are known to influence net methylmercury production and mercury accumulation in food webs. Increases in food web accumulation would exacerbate current concerns over exposure of humans and wildlife to mercury in the Estuary. CALFED restoration actions can be expected to affect mercury bioaccumulation on a local scale. Flooding of upland areas, altered hydrological regimes, and use of dredged material for wetland creation may create conditions favoring enhanced net methylmercury production in tidal wetlands. The extent of increases in methylmercury production may be minimized through thoughtful selection and design of restoration projects. Given the well established associations of net methylmercury production with flooding of uplands and with the percentage of wetlands within a watershed, it is probable that regional increases in mercury bioaccumulation will also occur. From a management perspective, the prudent course would be to minimize risk as much as possible based on existing knowledge while conducting the research needed to reduce the negative impacts of future restoration projects and the monitoring needed to assess regional and local impacts. We recommend: 1) A serious, multifaceted research effort on mercury should be an on-going part of CALFED restoration over the next 20 years. 2) Long-term monitoring should be performed to ascertain the impact of CALFED actions on mercury bioaccumulation on both a regional and local scale. 3) Detailed surveys should precede restoration projects to document existing mercury concentrations in affected areas and to evaluate the potential for increased food web accumulation. 4) Spatial patterns in mercury accumulation within marshes, among marshes in the same region, and among marshes in different regions are likely to exist and need to be understood. 5) Mercury transfer through the food web to species at risk, including humans, must be better understood.

EFFECT OF DIETS AND WATER TEMPERATURES ON THE GROWTH OF SACRAMENTO SPLITTAIL (*POGONICHTHYS MACROLEPIDOTUS*) LARVAE

D.F. Deng[1], Swee Teh[*2], F.C. Teh[2], and S.S.O. Hung[1]

[1]**Department of Animal Science, University of California, Davis, Davis CA 95616**

[2]**Department of Anatomy, Cell Biology, and Physiology, School of Veterinary Medicine, 1321 Haring Hall, University of California, Davis, CA 95616, Phone: 530-754-8183, Fax: 530-754-7788, e-mail: sjteh@ucdavis.edu**

There is no information on the optimum diet and water temperature of culturing Sacramento splittail (*Pogonichthys macrolepidotus*) under laboratory conditions. A four-week growth trial using a 4x3x2 factorial design (4 diets, 3 water temperatures, 2 replication of 100 larvae each) was conducted with splittail larvae (16 day post-hatch, 3.1 ± 0.5 mg and 8.9 ± 0.7 mm) in a recirculation system. The four diets were three commercial feeds (BD, BK, SC) plus a laboratory purified-casein (PC) diet and the three water temperatures were 18, 22, and 26 °C. Specific growth rate, total length, condition factor, and whole body moisture were significantly ($P < 0.05$) affected by the diets and water temperatures, but mortality was only affected by the diets. Interaction of diet and water temperature was significant for the specific growth rate, total length, whole body water, and mortality but not for condition factor. Larvae raised at 26 °C grew faster and thus they were longer and heavier than those at 18 °C. Larvae fed the BD and SC diets had lower specific growth rate and higher mortality than those fed the BK and PC diets. These results suggested that the commercial BK feed and laboratory PC diet and a water temperature of 22 to 26 °C were optimal for splittail larvae.

DO HERBICIDES IMPAIR PHYTOPLANKTON PRIMARY PRODUCTION IN THE SACRAMENTO-SAN JOAQUIN RIVER DELTA?

Jody L. Edmunds[*1], K.M. Kuivila[2], B.E. Cole[1], and J.E. Cloern[1]

[1]**U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025**
Phone: 650-329-4591, Fax: 650-329-4327, e-mail: jedmunds@usgs.gov

[2]**U.S. Geological Survey, Placer Hall, 6000 J Street, Sacramento, CA 95819**

The effect of herbicide concentration on the maximum rate of phytoplankton primary production (Pmax) was examined for 53 water samples collected at 9 sites in the Sacramento-San Joaquin River Delta between May and November, 1997. Samples were analyzed for Pmax and the concentrations of diuron, atrazine, cyanazine, simazine, thiobencarb, and hexazinone. The herbicide concentrations ranged from undetectable to 2.1 µg/L, with 50% of the values (*n* = 318) between 0 and 0.018 µg/L. Herbicide concentrations in 52 of the water samples were below the lowest observable effect concentrations (LOECs) that have been reported in laboratory experiments to inhibit primary production. Pmax ranged between 2 and 11 mg C (mg chl a-h)$^{-1}$ for the 52 samples where the herbicide concentrations were less than any reported LOEC. However, for the one sample where the diuron concentration (2.1 µg/L) exceeded the reported LOEC of 2.0 µg/L, Pmax was the lowest observed during the study, 0.9 mg C (mg chl a-h)$^{-1}$. Herbicide concentrations measured at the Delta study sites do not appear to limit phytoplankton primary production on a system-wide scale. However, localized occurrences of elevated herbicide concentrations exist and may inhibit primary production at local scales. In our study we did not explore the possibility that herbicide exposure events can selectively inhibit growth of sensitive species and therefore shape phytoplankton community composition.

MODELING GROUNDWATER SURFACE WATER INTERACTIONS TO RESTORE FALL FLOWS IN THE LOWER COSUMNES RIVER BASIN

J. Fleckenstein*, E. Suzuki, and G. Fogg

Land, Air and Water Resources—Hydrologic Sciences, University of California, Davis, 1 Shields Ave., Davis, CA 95616, Phone: 530-752-1372, e-mail: janfleck@ucdavis.edu

Decreasing fall flows in the Cosumnes River have led to declining fish populations of endangered chinook salmon. The role of groundwater-surface water interactions in the decline of fall flows is investigated by means of a numerical model that is based on field data. Currently channel seepage from the river in the late summer and fall months often exceeds channel inflows, causing cessation of stream flow. Preliminary simulations suggest that a 50% reduction in regional groundwater pumping would reconnect the river with the regional aquifer and reduce channel seepage losses to an extent that September and October river flows would allow fall migration and spawning of chinook salmon. The reduction in groundwater pumping, however, would create average annual water shortages of 36% in the model area. Long-term management strategies to restore sustained baseflow to the Cosumnes River hinge on the interaction with the regional aquifer system, and how initiatives such as artificial recharge and conjunctive use can effect recovery of groundwater levels. Success of artificial recharge in turn will depend on a complex alluvial fan architecture that includes both laterally discontinuous and laterally extensive hydrofacies. The role of such geologic heterogeneity on artificial recharge and baseflow restoration is being investigated through geostatistical modeling of the hydrofacies together with regional-scale modeling of groundwater flow. Floodplain restoration and set back levees, as suggested for the Cosumnes River as means of flood prevention and habitat restoration, may provide viable opportunities for additional groundwater recharge. Optimal locations of recharge sites and timing of water level responses will be addressed in this context.

A PRODUCTIVITY-BASED MODEL OF TIDAL HYDROLOGY INFLUENCE ON MARSH VEGETATION

Theodore C. Foin*, S.D. Culberson, and M.R. Pakenham-Walsh

Dept. of Agronomy and Range Science and Graduate Group in Ecology, University of California, Davis, CA 95616, Phone: 530-754-7910, Fax: 530-752-4361, e-mail: tcfoin@ucdavis.edu

Comparative analysis of the vegetation in three tidal marshes (Petaluma Marsh -- Petaluma River, Fagan Slough - Napa River and Suisun Marsh - Sacramento-San Joaquin Delta) demonstrates that tidal hydrology and salinity are the two most important influences on the identity, productivity and distribution of tidal marsh vegetation species in the San Francisco Estuary. The zone of regular tidal incursion near channels supports locally maximal above-ground production and strong dominance by a small number of taller species. The dominant plants are 0.5 to 4 m tall and form large patches. Inland from the channel, reduced frequency of tidal incursion results in lower plant productivity, limited plant height (0.2 to 0.5 m), less concentrated dominance, more pronounced patches and higher species diversity. At the upper end of the marsh, productivity is highly seasonal and plants are more adapted to tolerate low soil moisture and/or higher salinity. Diversity is minimized and the herbaceous vegetation tends to be very short (0.1 to 0.4 m).

This model is a further elaboration of a vegetation-hydrology model originally developed for Petaluma Marsh. Using hydrology and salinity as key driving variables, the model satisfactorily accounts for the reduced zone of influence seen for mosquito ditches as well as for the distribution and abundance of the vegetation in all three marshes. We expect the quantitative model to result from this research to predict the equilibrium vegetation and landscape structure for San Francisco Estuary marsh vegetation under various hydrologic conditions. A satisfactory understanding of productivity, diversity, and vegetation structure in relation to hydrology and salinity should improve our ability to restore vegetation landscapes that benefit both the fishes and endangered tidal marsh species which are the specified measures of satisfactory performance in a rapidly growing number of marsh restoration programs in the San Francisco Estuary.

COMPARISON OF FISH SALVAGE TRENDS BETWEEN SELECTED NATIVE AND NON-NATIVE FISHES

Steven Foss*

Calfornia Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: sfoss@delta.dfg.ca.gov

Two large fish salvage facilities in the south Delta of the San Francisco Bay Estuary, the Central Valley Project's Tracy Fish Collection Facility and the State Water Project's Skinner Fish Protective Facility, divert (salvage) fish from exported water. Both facilities use a louver-bypass system to collect fish, which are then transported to release sites in the Delta. I will examine inter-annual and intra-annual abundance and density trends of selected native and non-native fish salvaged during the last 21 years (1979 to 1999). Salvage trends of native species, including Sacramento pikeminnow, Sacramento blackfish, tule perch, longfin smelt, and splittail will be compared to those of non-native species, including American shad, threadfin shad, non-native centrarchids, and inland silverside. I will also use correlation analysis to look at possible associations of salvage abundances and densities with factors hypothesized to influence salvage, such as season, time of day, water temperature, pump (export) rate, water year type, and percent of Delta inflow diverted.

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CALFED ENVIRONMENTAL WATER ACCOUNT AND WATER MANAGEMENT STRATEGY

David K. Fullerton[*1], T. Cannon[2], and R. Brown[3]

[1]**Natural Heritage Institute, 2140 Shattuck Ave., 5th Floor, Berkeley, CA 94704**
Phone: 510-644-2900, Fax: 510-644-4428, e-mail: dfullerton@n-h-i.org

[2]**Foster Wheeler Environmental Corp., 3947 Lennane Drive, Suite 200, Sacramento, CA 95834**

[3]**Jones & Stokes Associates, 2600 V St., Sacramento, CA**

CALFED's Water Management Strategy (WMS) hopes to improve water supply reliability, water quality, and health of Central Valley and Bay-Delta ecosystems. The WMS framework includes an Environmental Water Account to reduce the impact of Delta water diversions on important fish populations and their habitat. An EWA would obtain water assets including storage water, export reductions, and other assets to be used to enhance river flows and limit south Delta exports. Modeling of project operations indicates that salvage of salmon, delta smelt, and other important fish can be reduced as much as 50% with EWA and B2 export reductions. Benefits would be achieved from a combination of changing the timing of exports and reductions in deliveries to water users. Export reductions often had the additional environmental benefits of maintaining higher upstream reservoir levels or higher Delta outflow. Application of the EWA also had potential synergistic benefits to water quality and water supply, as well as negative effects on water supplies and other factors. A unique aspect of the EWA is that its assets need only be used as collateral as debts are often repaid when Mother Nature replenishes borrowed water. EWA assets that proved effective included water stored in groundwater banks south of the Delta, water stored in South of Delta reservoirs (i.e., San Luis Reservoir), and water stored within and upstream of the Delta. EWA assets and capabilities also enhanced the utility and benefits of other environmental water assets including those of the CVPIA b2 program and CALFED's Ecosystem Restoration Program (ERP). The EWA in combination with the environmental protections of the 1995 Water Quality Control Plan, the CVPIA, and other CALFED programs including the ERP offer a positive prognosis for the recovery of important fish populations including chinook salmon, steelhead, delta smelt, splittail, and other native species.

LIFE TABLE MODELING OF STRIPED BASS (*MORONE SAXATILIS*) IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

Russ Gartz*

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: rgartz@delta.dfg.ca.gov

Data from the California Department of Fish and Game Egg and Larval Survey, Midsummer Townet Survey, Fall Midwater Trawl Survey, and Adult Striped Bass (Morone saxatilis) Tagging Program were used to construct life table models for striped bass in the Sacramento-San Joaquin Estuary for the years 1990 and 1984. One of the major goals of this investigation was to evaluate the Department of Fish and Games's ability to describe the life history of striped bass in the estuary. The other major goal was to evaluate if the current sampling programs can be used to adequately describe factors affecting striped bass abundance in the estuary. Results from this study will be used to describe other year classes that have sufficiently available data.

DAY-NIGHT DIFFERENCES IN ABUNDANCE AND COMPOSITION OF MACROZOOPLANKTON/MICRONEKTON OF SAN FRANCISCO BAY

Darren S. Gewant*, S. Darren, and S.M. Bollens

Department of Biology and Romberg Tiburon Center for Environmental Studies, San Francisco State University, San Francisco, CA 94132, Phone: 415-338-7011, e-mail: dgewant@sfsu.edu

The objective of this study was to determine the community composition and abundance of macrozooplankton and micronekton in the San Francisco Bay, with special reference to possible differences between daytime and nighttime sampling. Daytime and Nighttime samples were collected using a Methot trawl (4.0 m2 / 3 mm mesh) at 6 stations spanning San Pablo Bay, Central Bay and South Bay on several dates from November 1998 to August 2000. *Engraulis mordax* and *Spirinchus thaleichthys* were the most abundant fishes sampled, and *Crangon franciscorum* and *Synidotea laticauda* the most abundant invertebrates (although large densities of *Pleurobrachia bachei* occurred in the South Bay in February 2000). Significant differences in abundance between daytime and nighttime tows occurred at all stations for both fishes and invertebrates. At several stations daytime densities were zero or near zero while nighttime densities were two to three times greater (e.g., total density = 190/1000 m^3).Composition of invertebrates also varied significantly between daytime and nighttime, with clear differences in dominant species (e.g., C.franciscorum were totally absent in August and November 1999 daytime samples but abundant in nighttime samples). Less day-night variation occurred in the composition of fishes, however nighttime tows consistently resulted in greater species richness. These marked day-night differences in abundance and composition may be attributed to net avoidance in the daytime and/or migration of benthopelagic organisms off the bottom and into the water column during nighttime hours. In either case the significant differences between day and night catches should be taken into account in interpreting past studies and designing future surveys.

GENETIC CHARACTERIZATION USED TO IMPROVE JUVENILE CHINOOK MANAGEMENT

Sheila L. Greene*

Environmental Services Office, California Department of Water Resources, 3251 S Street, Sacramento, CA 95816, Phone: 916-227-7538, Fax: 916-227-7554, e-mail: sgreene@water.ca.gov

Until recently, there were limited tools to help manage the juvenile life stage of endangered and threatened runs of Central Valley chinook. Although the fours runs of Central Valley chinook, fall, late-fall, winter and spring, were named by the season adults immigrate upstream, due to varying adult holding time, egg incubation and juvenile rearing and growth rates, the young emigrate to the ocean as mixed populations. When winter-run was listed under the federal and State endangered species acts in 1989, the only tool to distinguish them from the other runs was growth rate and time of emergence, also known as length-date criterion. Since then, IEP, AFRP, and CALFED have funded research through the University of California on the genetic characterization of Central Valley chinook. Genetic characterization is used similarly as traditional phenotypic characterization. The advantage is more potential to find distinguishing characteristics among closely related populations using genetic material. The results have been a large degree of differentiation of winter-run, and to a lesser degree, spring-run. The power to distinguish winter-run has been strong enough to identify them individually. The IEP has been collecting chinook tissues from juvenile chinook for genetic characterization at the Delta export facilities since 1996. We have learned the number of winter-run, based on genetic characterization, lost at the export facilities is about half the number lost based on length-date criterion. From individual identification of winter-run, we learned that growth rate and emergence time do not characterize genetic winter-run emigrating through the Delta well. Genetic winter-run were salvaged at a more consistent length, but over a longer time period then estimated using length-date criterion. This new tool, genetic characterization, will help us better manage water project operations to minimize impacts to winter- and spring-runs, and improve our understanding of chinook life history and management of the species.

SEASONAL AND EVENT-DRIVEN INVERTEBRATE POPULATIONS DYNAMICS ON A COSUMNES RIVER FLOODPLAIN

Edwin D. Grosholz* and K. Forshay

Dept. of Environmental Science and Policy, University of California, Davis, 1 Shields Ave., Davis, CA 95616 Phone: 530-752-9151, Fax: 530-752-3350, e-mail: tedgrosholz@ucdavis.edu

Successful restoration of seasonal river floodplains requires reconstructing natural patterns of inundation and dewatering that encourage the growth and survival native fishes and invertebrates. What is needed is an understanding of how episodic flooding events interact with seasonal changes in hydrology to influence the abundance of key native species. Here we quantify changes in the abundance and biomass of invertebrate species in response to both episodic, event-driven flooding cycles and more continuous, seasonal changes on a floodplain of the Cosumnes river. We found that the zooplankton abundance and biomass cycled dramatically with event-driven floodplain inundation with steep declines in density after inundation. However, independent of the episodic flooding events, we also found strong seasonal changes in the abundances of several of the dominant taxa. Early in the season, we found high abundances of larger cladoceran taxa (*Daphnia* and *Sida* spp.) and fewer calanoid copepods relative to later in the season. The abundances of these taxa were negatively correlated independent of the episodic, event-driven changes. Overall, changes in biomass mirrored changes in the dominant, larger taxa such as the large cladocerans. Evidence from light trap data suggests that some of the declines in large zooplankton may have been the result of fish predation. The nature of these seasonal changes follow predictably from the development of the floodplain from a largely river-influenced system to a more insular, static system. These results underline how important timing, duration and other characteristics of inundation are for the dynamics of floodplain invertebrates, and the necessity of incorporating this information into restoration plans.

MODEL OF FISH MOVEMENT TO ASSESS FISH COLLECTION EFFICIENCY IN A LOUVERED CHANNEL

James W. Haefner[*1] **and M.D. Bowen**[2]

[1]**Department of Biology and Ecology Center, Utah State University, Logan, UT, 84322-5305**
Phone: 435-797-3553, Fax: 435-797-1575, e-mail: jhaefner@biology.usu.edu

[2]**U.S. Bureau of Reclamation, Fisheries Applications Research Group**
P.O. Box 25007, Denver, CO 80225-8290

We present the design and results of a simulation model of hydrodynamics and fish movement in a louver-type fish diversion facility similar to one in the Sacramento-San Joaquin Delta at Tracy, California. The model is based on the fluid forces within the channel, allometric relations, and the energy and thrust characteristics of relevant fish species. Fish collection efficiency is positively correlated with fish size within a species as a power function of size, but depends on species-specific maximum thrust output and initial energy level and entry point to the channel. Using literature values for physiological and biophysical parameters, the expected maximum efficiency is about 0.75 when upstream channel velocity is 0.61 m/s and bypass velocity is 0.77 (ratio = 1.2). Efficiency increases as the velocity at the upstream end of the channel increases. The predicted efficiencies for six important species using size distributions observed at the Tracy facility are chinook salmon (0.81), splittail (0.70), striped bass (0.81), American shad (0.65), white catfish (0.80), and delta smelt (0.66).

PLANT COMMUNITY RESPONSES TO TIDAL RESTORATION IN MODERATELY SUBSIDED DIKED MARSHES

Laura A. Hanson*, K.P. Malamud-Roam, and A.M. Brown

Contra Costa Mosquito and Vector Control District, 155 Mason Circle, Concord, CA 94520
Phone: 925-685-9301 ext. 119, Fax: 925-685-0266, e-mail: pipefish@earthlink.net

Tidal action was restored to two sections of the Point Edith Marsh Complex, south of Suisun Bay in 1991 and 1996. Prior to tidal restoration the marshes had been diked for approximately 80 years and were characterized by muted tidal action, 20 to 40 cm subsidence, and summer hypersalinity periods. The dominant vegetation species include *Lepidium latifolium* (peppergrass), *Salicornia virginica* (pickleweed), *Distichlis spicata* (salt grass), *Typha* spp. (cattail), *Scirpus robustus* (alkali bulrush), *Juncus balticus* (wire rush), and *Atriplex triangularis* (fat hen). After reintroduction of full tidal action, hypersaline soils were quickly reduced to levels indicative of a brackish tidal marsh. Changes in vegetation composition and cover were observed with full tidal flow. These changes were compared to a analogous control section control of the marsh with highly muted tidal regimes. The greatest change in percent cover at both sites occurred in cattail and pickleweed. There was a regional increase in *Typha* ssp. cover, and decrease in *Salicornia virginica*. *Typha* ssp. cover, more than doubled since the 1996 baseline data, (the control increased about half that amount). The converse occurred with *S. virginica* where the cover decreased to less than half the baseline data, and the decline was less than half that at the control. Higher than average rainfall in the years following tidal restoration, combined with soil desalinization due to tidal enhancement, apparently caused cattail encroachment in excess of the amount expected based on our previous observations.

PATTERNS OF ADULT FISH USE ON THE YOLO BYPASS FLOODPLAIN

William C. Harrell*, T. Sommer, W. Batham, and R. Kurth

California Department of Water Resources, 3251 S Street, Sacramento, CA 95816
Phone: 916-227-7619, Fax: 916-227-7554, e-mail: bharrell@water.ca.gov

In this poster we describe initial results from a study to examine adult fish diversity, abundance, habitat use and timing of occurrence in the Yolo Bypass floodplain, a region of known importance for juvenile fish rearing. A large cylindrical fyke trap was used to capture adult fish between November 1999 and June 2000. We observed over 1,400 individuals representing 19 species including federally listed winter-run and spring-run chinook salmon, splittail and sport fish such as white sturgeon, striped bass and American shad during the sampling period. Flow pulses immediately preceding floodplain inundation apparently triggered upstream movement of a suite of native fish (Sacramento blackfish, splittail, sucker, and pike minnow). However, we also observed immigration of chinook salmon, white sturgeon, Sacramento sucker, American shad and striped bass during low flow periods, when there was no upstream connection to the Sacramento River. Concurrent screw trap sampling indicated that these migrations resulted in successful spawning of Sacramento splittail, American shad and striped bass. These results indicate the Yolo Bypass floodplain represents an important migration corridor and spawning habitat for Delta fish; however, better upstream passage is needed particularly during low flow periods.

SALINITY IMPACT SCREENING OF DELTA ISLAND RESTORATION AND RECLAMATION SCENARIOS

Callie B. Harrison*, C. Enright, and K. Guivetchi

California Department of Water Resources, 3251 S Street Sacramento, CA 95816
Phone: 916-227-2489, Fax: 916-227-7554, e-mail: callieh@water.ca.gov

The Department of Water Resources Suisun Marsh Branch conducted a reconnaissance level modeling analysis to evaluate impacts of island reclamation alternatives for ecosystem restoration and salinity control in the western Delta. The study focused on alternative configurations for the Sherman Lake, Big Break and Franks Tract areas. The analysis was conducted after recent modeling analysis indicated salinity reduction in the Delta from selective levee breaches within the Suisun Marsh. Combinations of island reclamation and engineered breaches were identified that provide opportunities for ecosystem restoration and central and south Delta salinity reduction.

The DWRDSM1 (Suisun Marsh version) model was used. A base model run was made simulating historical conditions in drought water years 1991 and 1992. All alternative configuration simulations and salinity impact analysis focus on water year 1992.

Twenty-four alternatives were screened using the DWRDSM1 model. The investigation indicates that some Sherman Lake alternatives provide marginal salinity reduction, while Big Break and Franks Tract alternatives show potential for significant central and south Delta salinity reduction. The study also shows the utility of applying one-dimensional models for rapid screening of alternative island restoration/reclamation alternatives. Further alternatives refinement should be pursued with higher dimensional models.

FABRIC AND VEGETATION FACILITATE DEPOSITION WITHIN RIVERINE REVETMENT

Jeffrey A. Hart*

Habitat Assessment and Restoration Team, Inc., 13737 Grand Island Road, Walnut Grove, CA 95690
Phone: 916-775-4021, Fax: 916-775-4022, e-mail: jhart@ns.net

Natural plant establishment and restoration efforts on riverine revetment cobble and riprap sites has sometimes proven problematic, often due to lack of sufficient soil in the rock interstices. Sediment depositional and erosional processes depend upon various factors, including vegetational characteristics. This study was designed to determine how various configurations of plants and fabric affect erosional and depositional processes on a revetment site along the Lower American River in Sacramento, California. The experimental methods included 8 treatments, each measuring 2 meter x 2 meters, that made use of different combinations of soil, annual grasses, sedges, coir fabric, and an inner fabric cloth. Each treatment was replicated 7 times, and these were randomized along a 112 meter section of river embankment. The entire site flooded during the 1996-1997 for more than three months. After winter floods subsided, the study plots were studied to determine relative deposition and erosion by measuring the amount of rock surface exposed within each plot compared to the before flood conditions. The treatments ranged from 84% rock exposed for the control (soil alone) to 1% for the full treatment of soil, inner blanket, coir, annuals, and sedge. The results of our experiment highlight the importance of herbaceous plants and landscape fabric in providing the amount and quality of roughness necessary to protect revetment sites from scour and to encourage sediment deposition, conditions necessary for successful riverine habitat restoration.

CONDITION OF FISH PASSED THROUGH A PUMP AT THE TRACY FISH FACILITY, CALIFORNIA

Louis A. Helfrich[*1], C. Liston[2], B. Mefford[3], and R. Bark[4]

[1]**Virginia Polytechnic Institute and State University, Blacksburg, VA 24061**
Phone: 209-836-6268, e-mail: lhelfrich@mp.usbr.gov

[2]**Bureau of Reclamation, MP-400, Sacramento, CA 95825**

[3]**Bureau of Reclamation, D-8560, Denver, CO 80225**

[4]**Bureau of Reclamation, D-8290, Denver, CO 80225**

Fish lifts are being tested at Tracy (South Delta) to determine potential use for improving fish salvage at large water diversions. Water and fish from existing bypass flows (198 to 395 liters per second) were lifted to an above ground pool. Observations were made on experimental releases and naturally entrained fish over a range of impeller speeds, flow rates, and environmental conditions (130 paired trials were conducted from December 1998 to July 1999). Passage survival, descaling, and non-lethal injury rates of tagged splittail and chinook salmon inserted into the pump inflows were compared with control fish inserted into the outflows. There was no significant effect on immediate or latent mortality, descaling, or injury rates, except for a 96-h mortality of splittail in June. Immediate survival rates of pumped splittail and salmon averaged 99%, and cumulative (96 h) survival averaged 93% and 96%, respectively. Average scale loss on splittail and chinook was minimal (1.9% and 2.4%) and the incidence of injury to head, eyes, skin, and fins was low (<15%) and similar between quality control, control, and treatment fish. Survival of wild fish (24 species; 7,197 fish) entrained from the Delta during pumping trials was also high (99%). The internal helical pump at Tracy effectively transported a diversity of species and sizes of fish in large numbers with low mortality and injury over a range of velocities and environmental conditions. We believe this pump represents acceptable technology for future CALFED fish screening and salvage facilities in the south Delta and other sites.

AGE AND GROWTH DYNAMICS OF DELTA SMELT EARLY LIFE HISTORY

James A. Hobbs*[1], D.P. Martasian[1], P.B. Moyle[2], W.A. Bennett[1]

[1]**Bodega Marine Laboratory, University of California, Davis, 2099 Westside Rd., Bodega Bay, CA 94923, Phone: 707-875-2035, Fax: 707-875 2089, e-mail: jahobbs@ucdavis.edu**

[2]**Wildlife, Fish, and Conservation Biology, University of California, 1 Shields Ave., Davis, CA 95616**

Through the utilization of otolith microstructure analysis, delta smelt larvae and juveniles from 15 stations within the Delta were aged and growth parameters measured. Preliminary analysis focuses primarily on juvenile fish caught in the June Real Time Monitoring Survey and the July Summer Townet Survey. Hatchdates were backcalculated from the otoliths increments and a Paired t-test revealed a significant difference in mean hatchdate between fishes collected in June and July suggesting two distinct cohorts exist (June Real Time cohort mean = Julian day 109 n = 35, sd = 6.7 and July townet cohort mean = 140 Julian day n = 46, sd = 7.8, P = 0.001). Hatchdate frequency distribution analysis suggests approximately 13-15% of July caught fish had hatchdates overlapping hatchdates of fishes caught in June, indicating potential mortality rates as high as 87% to 85%. The size-at-age was also backcalculated using the biological intercept method (Campana 1990). The mean growth rate was 0.39 mm/d, sd = 0.038 Growth in the first 15 days of life is relatively slow with a mean growth rate of 0.18 mm/d. This slow growth may coincide with exogenous feeding in larvae after yolk sac absorption. From 15 to 90 days growth is relatively fast at 0.55 mm/d. After 90 days of life, linear growth slows significantly to 0.23 mm/d. This reduction in daily linear growth coincides with the transition to the adult stage at about 45-mm fork length. Future investigations include the estimation of instantaneous daily mortality rates with the otolith increment frequency method and comparative analysis of growth rates throughout the Bay-Delta estuary.

THE PREVALENCE OF A PARASITIC NEMATODE AND THE EFFECT ON REPRODUCTION IN DELTA SMELT

James A. Hobbs*, D.P. Martasian, and W.A. Bennett

Bodega Marine Laboratory, University of California-Davis, 2099 Westside Rd., Bodega Bay, CA 94923, Phone: 707-875-2035, Fax: 707-875-2089, e-mail: jahobbs@ucdavis.edu

Delta smelt (*Hypomesus transpacificus*) an endangered native fish of the San Francisco Bay-Delta Estuary has experienced a dramatic decline in the population in recent years. Meanwhile the factors regulating the population dynamics are largely unknown. In 1999-2000, 480 delta smelt were collected in the California Department of Fish and Game Fall Midwater Trawl Survey, 23 fish were collected from the Bay Study Survey in February 2000 and 69 fish were collected from the federal pumping facilities at Tracy in March 2000. Delta smelt were dissected and the prevalence of nematodes quantified. The overall prevalence of nematode infestation was relatively low at 4%, while the prevalence of nematode infestation in fish identified as 1+ year old cohorts using otolith microstructure analysis was 62%. Delta smelt from archived samples at UC Davis (1975-1996) were also examined for nematode prevalence. From this survey it was apparent that nematode infestation in the delta smelt population might have occurred as recently as 1989. The 23 fish from the Bay Study and the 69 fish collected at the federal pumping facilities were analyzed for Gonadosomatic Index (GSI). A two-factor ANOVA for nematode prevalence indicated GSI was significantly lower in infested individuals than in uninfested individuals in February and higher in infested individuals than uninfested individuals in March (P = 0.001, Month*Prevalence). This analysis indicates that the nematode infestation may delay oocyte maturation and spawning in the delta smelt population. In the light of recent discoveries concerning the tidal influence on spawning behavior and egg hatching of delta smelt, delayed spawning may disrupt the recruitment dynamics and prove detrimental to the delta smelt population.

FISH SCREENING PERFORMANCE AT CONTRA COSTA WATER DISTRICT'S NEW OLD RIVER INTAKE

Lisa M. Holm* and D.A. Briggs

Contra Costa Water District, 1331 Concord Avenue, P.O. Box H20, Concord, CA 94524-2099
Phone: 925-688-8106, Fax: 925-688-8142, e-mail: lholm@ccwater.com

Contra Costa Water District's (CCWD) screened Los Vaqueros Reservoir intake on Old River near the Highway 4 crossing came on line in the summer of 1997. Fish monitoring data at the new intake, salvage, and abundance data in Old River during the spring/ summer of 1999/2000 suggest that CCWD's intake design and operations are extremely successful in preventing entrainment of endangered species like delta smelt, Sacramento splittail, and winter-run chinook salmon. For example, from March 15, 1999 through July 15, 1999 salvage at the State Water Project (SWP) and Central Valley Project (CVP) export facilities was as high as 6,594 Delta smelt and 3,776 Winter-run salmon per day, while 1999 monitoring at CCWD's Old River Intake captured none.

"Real Time Monitoring," directed by the CALFED Operations Group with the purpose of providing timely fishery data for consideration in water project operations, was developed by the Interagency Ecological Program's (IEP) Real Time Monitoring Project Work Team (PWT). This effort collects fish from "strategically selected" locations and surveys the Delta for small juvenile fish and quantifies salvage at the Banks and Tracy Pumping Plants.

Data from IEP monitoring, fish screen monitoring and pumping operations are analyzed to compare the efficacy of fish screens at the SWP Banks and USBR Tracy Pumping Plants and CCWD's Old River Pumping Plant. The unique positioning of CCWD's Old River Fish Screen facility along the side of a river with high tidal sweeping flows and relatively low pumping capacity is proving to be very successful in minimizing impacts to fisheries independent of the flow dynamics and fish populations in Old River. The success of this type of screen needs to be taken into account as CALFED implements its ambitious program for constructing and operating fish facilities.

THE PROPOSED SAN FRANCISCO BAY NATIONAL ESTUARINE RESEARCH RESERVE: A PARTNERSHIP FOR RESEARCH, EDUCATION AND STEWARDSHIP

Todd E. Hopkins*

San Francisco Bay National Estuarine Research Reserve, 3152 Paradise Dr., Tiburon, CA 94920
Phone: 415-338-3703, Fax: 415-435-7120, e-mail: thopkins@sfsu.edu

The proposed San Francisco Bay National Estuarine Research Reserve (SF Bay NERR) is a partnership between the National Atmospheric and Oceanographic Administration, the SFSU Romberg Tiburon Center, and three component sites managed by California State Parks, the Solano County Farmlands and Open Space Foundation, and the East Bay Regional Park District. The three component sites: China Camp State Park (1,640 acres), Rush Ranch Open Space Preserve (2,070 acres), and Brown's Island Regional Shoreline (595 acres), represent some of the few undiked tidal marsh, baylands and adjacent uplands much as they existed in the 1800s.

Proposed as the 26th NERR site the SF Bay NERR will participate in national programs of continuous weather and water quality monitoring, coastal zone decision-maker workshops, graduate research fellowships, and protected-area GIS. Component properties will continue to be owned and managed as they are currently and no new federal regulations come into effect as a result of this partnership. The goal of the SF Bay NERR is to increase the level of scientific information utilized by coastal decision-makers in the San Francisco Bay Estuary through integrated programs of research, monitoring, education and stewardship. A draft management and operations plan and environmental impact statement will be available for public comment in late 2000 or early 2001. While the ultimate decision for designation rests with NOAA, we are optimistic that the SF Bay Reserve will be designated in summer 2001. More information about the NERR system is at http://www.ocrm.nos.noaa.gov/nerr and information about the SFSU Romberg Tiburon Center and SF Bay NERR headquarters is at http://rtc.sfsu.edu.

SEASONAL PATTERNS AND FACTORS CONTROLLING THE OCCURRENCE OF DISSOLVED PESTICIDES IN THE SACRAMENTO-SAN JOAQUIN DELTA

Jacqueline R. Houston*, L.A. Allen, and K.M. Kuivila

U.S. Geological Survey, 6000 J Street, Sacramento, CA 95819-6129
Phone: 916-278-3052, Fax: 916-278-3071, e-mail: jhouston@usgs.gov

Many of the 150 agricultural-use pesticides applied throughout the year in the Central Valley are transported by rivers and eventually reach the Sacramento-San Joaquin Delta (Delta), where they pose a potential threat to aquatic life. The data from four separate studies were compiled to examine seasonal patterns of pesticide occurrence in Delta waters and to determine which factors control the occurrence of highly-used dissolved pesticides. The studies were done by the U.S. Geological Survey's San Francisco Bay Estuary Toxic Substances Hydrology Project over a period of nine years. Dissolved pesticides, specifically herbicides and insecticides, were analyzed in water samples collected from 40 sites throughout the Delta during which time the method and frequency of sampling varied.

Dissolved pesticide occurrence in the Delta is characterized by four major seasonal patterns that are identified by usage and transport mechanism. During the winter, dormant spray insecticides, such as diazinon, methidathion, and chlorpyrifos, are applied to orchards and then transported by rainfall into the Sacramento and San Joaquin Rivers. In the spring, pesticides such as carbofuran and chlorpyrifos, are detected in the San Joaquin River and Delta following late rains possibly due to application on alfalfa. In late spring and early summer, pesticides such as molinate, thiobencarb, and carbofuran, are transported into the Sacramento River from rice field release water. During the summer, irrigation return flow transports a variety of herbicides into the Delta.

In contrast to the pesticides observed in these seasonal patterns, there are a number of pesticides that are rarely, if ever, detected despite being applied in large amounts. The absence of these pesticides is explained by their chemical properties, such as low water solubility, rapid degradation rate, or high vapor pressure. This data analysis of patterns of pesticide occurrence can aid in the design of future monitoring studies.

DIRECT INGESTION OF ENVIRONMENTAL CONTAMINANTS: GEOPHAGY IN TWO SYMPATRIC SHOREBIRD SPECIES

Clifford A. Hui*[1] and W.N. Beyer[2]

[1]**U.S. Geological Survey, 278 Kerr Hall, University of California, 1 Shields Ave., Davis, CA 95616 Phone: 530-752-6420, Fax: 530-752-8561, e-mail: cliff_hui@usgs.gov**

[2]**U.S. Geological Survey, 12011 Beech Forest Rd., Laurel, MD 20708**

Ingestion of sediment during feeding is normal among many wildlife species. The consumption of contaminants from this source may be greater than that from the rest of the diet. For example, the principal source of health-impairing amounts of lead in Wood Ducks (*Aix sponsa*) at one site is sediment even though sediment ingestion is only about 1% of the total diet. Earlier reports show that birds commonly ingest much more than 1% sediment in their diet. Our study compared sediment ingestion by two species of shorebirds that are common in California coastal and wetland areas: black-bellied plovers (*Pluvialis squatarola*) and willets (*Catoptrophorus semipalmatus*). We sought to relate sediment ingestion to bill length and to feeding behavior with hopes of discerning some predictable parameters. Predictability would enable estimates of the potential threat to individual species by direct ingestion of contaminated soils. Black-bellied Plovers have short bills and peck while foraging, whereas Willets have long bills and probe with bills open in sediments. We anticipated that Willets would ingest more sediment than the plovers. Intestinal digesta were collected from these birds while over-wintering at the same beach. We used four different techniques: acid-insoluble ash and elemental markers of Al, Fe, and Ti in digesta. Results were similar. Plover digesta contained 29% sediment, and willet digesta contained only 3% sediment. These results are contrary to expectations. Sediment ingestion may be species specific and not linked to bill length or to probing behaviors.

GROUNDWATER BENEATH LEVEES

Edwin M. Hultgren* and R.K. Tillis

Hultgren-Tillis Engineers, 2520 Stanwell Drive, Suite 100, Concord, CA 94520
Phone: 925-685-6300, Fax: 925-685-6768, e-mail: hultgren@pacbell.net

Variations in groundwater conditions beneath Delta levees are presented. Data is derived from an eight-year study of groundwater beneath levees on 17 islands in the deep peat areas of the Delta. The study was funded by Delta Wetlands.

TRACY EXPERIMENTAL LABORATORY INVESTIGATIONS: LEAKY-LOUVER DEVELOPMENT PRELIMINARY RESULTS

Cathy Karp*, J. Kubitschek, C. Liston, and D. Weigmann

U.S. Bureau of Reclamation., D-8290, Bldg. 56, Denver Federal Center, 6th and Kipling, Denver, CO 80225, Phone: 303-445-2226, Fax: 303-445-6328, e-mail: ckarp@do.usbr.gov

The Tracy Experimental Laboratory Facility in Denver was constructed in 1998 to evaluate louver-bypass characteristics to improve fish screen efficiency at the Tracy Fish Facility. One aspect under development is the evaluation of a “leaky-louver” system that would separate large and small fish (i.e., divert larger fish to one holding system while passing smaller fish to a second holding system). Predation is known to occur at fish screening facilities, and separation of larger predatory fish is desirable. Thirty-four fish release-recapture experiments were conducted in a straight-line louver/side bypass experimental flume (10 ft wide, 80 ft long, 4 ft deep) at 9 louver configurations(15 degrees 2-inch, 4-inch, 6-inch; 30 degrees 2-inch, 4-inch, 6-inch; 45 degrees 2-inch, 4-inch, 6-inch; 3 releases per configuration). A mixture of large and small fish were released in each experiment and a large fish efficiency (proportion of fish 6-inch diverted into side bypass) and small fish efficiency (proportion of fish <6-inch passed through louver) were calculated. Fish that remained in the channel were excluded from the efficiency calculations. All experiments were conducted at 2-ft depth, 2.0 to 2.5 ft/s, and 1.2 bypass ratio. Preliminary analyses suggest larger fish were more effectively separated from smaller fish with the 30 degree 2-inch configuration. Velocity (sweeping and normal) increased from upstream to downstream along the louvers for all configurations. Additional tests are currently being conducted.

ECOLOGICAL COMPARISONS OF FOUR MARSHES NEAR SUISUN BAY, RESTORED TO INCREASED TIDE ACTION, AND REFERENCE MARSHES

Christopher L. Kitting*, J.T. Rees, and S.M. McGinnis

Shore Institute/Department of Biological Sciences, California State University, Hayward, CA 94542
Phone: 510-885-3001, Fax: 510-885-4747, e-mail: ckitting@csuhayward.edu

Marshes in San Francisco Estuary are being restored to higher tidal action. Our monitoring associates factors with increased fishes and their aquatic food webs. Approximately monthly for ~2 years, we non-destructively have sampled three marshes restored to tidal action, and three historic marsh sites nearby in this Suisun Bay Area. Thrown cage (epibenthos), plankton net, minnow trap, fyke net, and other ~monthly sampling generally detected little fish or invertebrate use of the historic reference marshes. In contrast, these methods at restored Peyton Slough near its source in a decade-old ("McNabney") restored Marsh, with salinities lowered experimentally by reclaimed water, yielded dense populations of invertebrates and of several of its 15 fish species, although only five fish species were native. The latter included a chinook salmon smolt. Further upstream in this marsh, 1 km from the outflow of an experimental reclaimed water marsh, supported six introduced and two native fish species through June, 1999. At that time, summer fish-kill conditions depleted aquatic populations throughout this marsh, and at another old marsh with little circulation during the warm summer. Crayfish and fishes recovered only slowly during the following year. Sampling at a muted marsh (Tubbs Island), receiving increased tidal amplitude in early 1999, similarly had permanent ponds, but negligible low-salinity sources, and yielded moderate population densities of six native and four introduced fish species and moderate invertebrate populations. A year after increased tidal action, this site showed a spring explosion of threatened delta smelt postlarvae, averaging 8, 20-mm -long (SL) plus 32 <15-mm-long individuals per m3. The following month, four of the deeper (~2-m deep) channels surrounded by Suisun marsh yielded relatively high populations of adult splittail (averaging ~3 individuals/500m3). Sources of permanent but tidally circulated ponds may be crucial for dense aquatic animal populations to colonize and persist in such marshes.

RESIDENT FISH POPULATION TRENDS IN THE SACRAMENTO-SAN JOAQUIN DELTA

Nina Kogut*

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: nkogut@delta.dfg.ca.gov

The Resident Fishes Monitoring Project has performed boat electrofishing surveys biennially since 1995 at 20 fixed locations throughout the Sacramento-San Joaquin Delta. During sampling in 1995-1999, 17 families and 40 species were observed. Centrarchids comprised over 80% of the fish observed during these 3 years, followed by non-native cyprinids and ictalurids. The only consistent changes in abundance during this period were an increase in catostomid catch and a decrease in ictalurid catch. Catches in 1995-1999 were compared with those from the same sampling locations as in the random 1980-1983 resident fishes survey. Comparisons of catch per unit effort for common families between 1980-1983 and 1995-1999 indicated no significant differences, except for a decreased catch of ictalurids. These comparisons should be treated with caution because of differences in sampling protocol and number of sampling instances.

THE MERCED RIVER SALMON HABITAT ENHANCEMENT PROJECT

Paula J. Landis[*1], K.J. Faulkenberry[2], and R.C. Mager[1]

[1]**California Department of Water Resources, 3251 S Street Sacramento, CA 95816**
Phone: 916-227-2490, Fax: 916-227-7554, e-mail: rcmager@water.ca.gov
[2]**California Department of Water Resources, 3374 East Shields Ave., Fresno, CA 93726**

San Joaquin fall-run chinook salmon populations have declined dramatically, in part due to spawning and rearing habitat loss. The Merced River Salmon Habitat Enhancement Project is a multi-phased project with partners in California Departments of Fish and Game and Water Resources, CALFED, and the Anadromous Fish Restoration Program. The project will restore functionality to 4.5 miles of the Merced River (RM 40.0-44.5) characterized by gravel pits, mining tailings, perched floodplains, warm water ponds, and sheet-flow. The first phase of the project, the Ratzlaff Reach, was completed in 1999. A 43-acre warm water pond was isolated from the main river channel, floodplain terraces were constructed and the narrow, confined channel was redesigned to function more naturally under the present flow regime. Planning, permitting and design are currently underway for phase two, the Robinson Site, to be constructed in 2001. This phase will include a suite of restoration actions to improve channel dynamics and sediment transport including channel reconfiguration, creation of large floodplains, and berm reconstruction. Through development and monitoring of the Ratzlaff Reach, changes in planning and design are being implemented in the next phases. These include extension of the planning and design phase to allow greater involvement by stakeholders and participation in AFRP's Adaptive Management Review Group Forum. Since the inherent characteristics of the Robinson site allow greater design flexibility than at the Ratzlaff site, options such as greater channel meander and larger floodplains are being planned. Re-vegetation plans are also being modified as a result of the Ratzlaff Reach experience. The budget for project monitoring has been increased to allow more comprehensive monitoring of geomorphology, fish passage, spawning, and revegetation as well as the budget for long term maintenance. Data collection and preliminary planning are ongoing for phase three, the Western Stone Reach. Construction of this reach is anticipated for 2002.

INVESTIGATIONS INTO THE STRESS RESPONSE OF THE GREEN STURGEON, *ACIPENSER MEDIROSTRIS*

Scott E. Lankford* and J.J. Cech Jr.

Dept. of Wildlife, Fisheries, and Conservation Biology, 1 Shields Ave., University of California, Davis, CA 95616, Phone: 530-752-8659, e-mail: selankford@ucdavis.edu

There is limited physiological and life history information available for the green sturgeon Acipenser medirostris. With a greater understanding of the life history variables faced by the green sturgeon it will be essential to understand how this fish responds, physiologically, to environmental changes such as salinity, temperature, flow regimes and dissolved oxygen. We have initiated a program investigating how the green sturgeon responds to environmental stressors and how that stress response is modified by developmental stages, time of day, and temperature. Preliminary results show that in response to an air emersion (45 seconds or 1 minute) the hypothalamic-pituitary-interrenal (HPI) axis is activated in the green sturgeon eliciting a post-stress rise in plasma corticosteroids, glucose, and lactate. Green sturgeon sac-fry are capable of responding to a stressful event as early as 8 days-post-hatch (dph) by endogenously producing a 3-fold increase (0.41 to 1.20 ng/ml) in whole body corticosteroids 30 minutes post-stress. We also measured the response to a 1 minute air emersion in young-of-the-year green sturgeon during the light and dark hours of the day. The stress response is augmented during night hours to a peak mean of 19.09 ng/ml cortisol and 190.57 mg/L lactate compared to a peak mean of 4.9 ng/ml cortisol and 166.69 mg/L lactate during day hours. We are currently investigating the modification of the stress response by temperature (11 and 19 °C), and additional work is planned to determine the stress response to environmental hypoxia and changes in salinity. By investigating the stress response of the green sturgeon to environmental stressors, we hope to provide insight into vulnerabilities of this fish to different life history variables. This information could assist natural resource managers in developing policies aimed at preserving the green sturgeon in the Sacramento-San Joaquin system. This work is supported by the CALFED Bay-Delta program.

SELENIUM BIOACCUMULATION KINECTICS FROM FOOD AND WATER IN THE BIVALVES *POTAMOCORBULA AMURENSIS* AND *MACOMA BALTHICA*

Byeong-Gweon Lee* and S.N. Luoma

U.S. Geological Survey, MS-465, 345 Middlefield Road, Menlo Park, CA 94025
Phone: 650-329-4466, Fax: 650-329-5590, e-mail: bglee@usgs.gov

Selenium in San Francisco Bay is introduced to north Bay from agricultural drainage systems as well as effluent from oil refineries. Selenium in this part of the estuary has been threatening the health of many aquatic organisms including upper trophic level fish and water fowl. Quantitative understanding of how internal biological and external environmental factors affect Se bioaccumulation is essential for assessing the risk of Se contamination. In the present study, radiotracer methods were employed to compare Se bioaccumulation from food (assimilation efficiency) and dissolved phase (influx rate), and loss kinetics (efflux rate) between two bivalves *Potamocorbula amurensis* and *Corbicula fluminea*. Effects of salinity and temperature on these kinetic parameters were also evaluated. *C. fluminea* fed algal food assimilated Se with significantly greater efficiencies (66% to 87%) than did the clams fed oxic sediments incubated with Se (IV) (20% to 37%). P. amurensis assimilated a similar percentage of Se with a similar rate from both food types (52% to 60%). Salinity affected Se assimilation efficiency differently between the two clams and the effects seemed to be related to their optimal salinity ranges. Increasing temperature from 5 to 21 °C increased the assimilation efficiency slightly. The influx rate of dissolved Se (IV) increased linearly with concentration and increased with temperature in both clams. Salinity had a negligible effect on dissolved Se influx rate. The rate constant of loss was greater for *P. amurensis* (0.029 d^{-1} at 8 psu and 0.049 d^{-1} at 20 psu) than for *C. fluminea* (0.014 d^{-1} at 0 psu and 0.01 d^{-1} at 8 psu). The results help explain Se bioaccumulation in these two estuarine clams, and can be used to model responses to Se exposures under various environmental conditions.

THE IMPORTANCE OF ACCURATE LARVAL FISH SURVEYS

Lisa M. Lynch*, J. Wang, L. Grimaldo, and B. Bridges

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7800, Fax: 209-946-6355, e-mail: llynch@delta.dfg.ca.gov

The importance of accurately identifying fish larvae collected during Interagency Ecological Program studies cannot be overstated. Biologists and managers rely on larval fish surveys to piece together early life history information and to validate decision-making regarding water project operations. For most fishes in the Delta, identification to family is easily achieved. Identification to species is often more difficult and requires rigorous training and verification. This is particularly true for identifying larval delta smelt which are easily confused with wakasagi. The purpose of this study is to develop a diagnostic key they will allow researchers to discriminate larval delta smelt from wakasagi. We are in the process of collecting voucher specimens of known origin from various locations to document a range of diagnostic characteristics. The voucher specimens are being confirmed through genetic analysis. Comparisons between morphometry of the two species will be attempted to be separated through multivariate analyses. Blind quality assessment trials on trained and untrained personnel will be used to test the validity of the key.

REHABILITATION OF SALMON HABITAT, RIVER CHANNEL AND FLOODPLAIN ON THE MERCED RIVER, RATZLAFF REACH

Randall C. Mager* and S. Spaar

California Department of Water Resources, 3251 S St., Sacramento, CA 95816
Phone: 916-227-7554, Fax: 916-227-2490, e-mail: rcmager@water.ca.gov

San Joaquin fall-run chinook salmon populations have declined dramatically, in part due to spawning and rearing habitat loss. The Merced River Salmon Habitat Enhancement Project is a multi-phased program with partners California Departments of Fish and Game and Water Resources, CALFED, and the Anadromous Fish Restoration Program (AFRP). Its goal is to restore functionality to a degraded section on the Merced River (river mile 40.0 to 44.5) that is characterized by 4.5 miles of gravel pits and tailings, perched floodplains, warm water ponds, and sheet-flow channel. The first phase of the project, Ratzlaff Reach (rm 40.0 to 40.5), included an abandoned gravel pit that had been captured by the river forming a 43 acre warmwater pond of slow moving water ideal for large and smallmouth bass that prey on juvenile salmon. It also prevented sediment transport since velocities were slowed to near stagnation during normal bankful. An engineered berm and designed channel were built to isolate juvenile salmon predator habitat from the river, improve river and floodplain dynamics under current flow regimes, increase the quantity and quality of spawning and rearing habitat for chinook salmon, create and enhance riparian vegetation, and create a more natural stream with improved sustainability. Constructed in 1999, the channel functioned as designed through a wide range of flows. Bankful was at 1,700 cfs, and the floodplain was inundated for 45 days at flows up to 3,500 cfs. Included in the project area were five spawning riffles, a backwater area for salmon rearing, and two innovative “equalization saddles” to allow hydraulic continuity between the pond and the river avoiding damage to the berms during rapid rises of the river. Post project monitoring of geomorphology, fish passage, spawning and revegetation continues to provide data for future designs of the next phases of the project area.

CORDYLANTHUS MOLLIS SSP. *MOLLIS* IN RESTORED TIDAL MARSHES

Karl P. Malamud-Roam*, A.M. Brown, and L.A. Hanson

Contra Costa Mosquito and Vector Control District, 155 Mason Circle, Concord, CA 94520
Phone: 925-685-9301 ext. 119, Fax: 925-685-0266, e-mail: pipefish@earthlink.net

Several discrete soft bird's beak (*Cordylanthus mollis* ssp. *mollis*) populations have been found in the Point Edith Marsh Complex. Two monitored sites include Swanton's Marsh and East Navy because of their identified populations of *C. mollis* ssp. *mollis*. Floristic surveys of were conducted during the flowering period (May-November). Soil and chemical characteristics were also measured. The deterioration of the existing levee Swanton's Marsh (west of Hasting's Slough and southwest of the oxbow) serve as the experimental site, and East Navy (east of the Naval Tidal area) serve as the "control site." West Navy (east of Hasting's Slough) was selected to for the germination and transplantation study, west of Hasting's slough in Swanton's Marsh. Dominant vegetation found near populations of *C. mollis* spp. *mollis* include *Salicornia virginica* and *Distichlis spicata*. Sub-dominants are *Scirpus americanus*, *Juncus balticus*, and *Triglochin maritima*. This species composition has remained fairly consistent through 1999. There was similar changes in vegetation cover and composition at the both the experimental and control sites. From the peak flowering period of 1995 to 1996 the percent cover of *C. mollis* ssp. *mollis* dropped by approximately 50%, however, from 1996 and 1999 the percent cover has remained nearly constant.

MERCURY CONTAMINATION FROM HISTORIC GOLD MINING IN THE BEAR AND SOUTH YUBA WATERSHEDS: BIOACCUMULATION IN FISH

Jason T. May*[1], C.N. Alpers[1], and R.L. Hothem[2]

[1]**U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA 95819-6129**
Phone: 916-278-3079, Fax: 916-278-3071, e-mail: jasonmay@usgs.gov

[2]**U.S. Geological Survey, 1 Shields Ave., Room 278, Kerr Hall, University of California, Davis, Davis, CA 95616-5224**

The management of federal lands with historic mining operations has received increased attention in recent years. In California, mercury used for gold extraction in mining areas of the Sierra Nevada continues to enter local and downstream water bodies, including the Sacramento-San Joaquin River Delta and the San Francisco Bay Estuary. Methylmercury, the most prevalent form of mercury in fish, has received considerable attention because it is a potent neurotoxin that tends to bioaccumulate in food webs. In April 1999, the U.S. Geological Survey, in cooperation with the U.S. Forest Service, the Bureau of Land Management, the U.S. Environmental Protection Agency, the State Water Resources Control Board, and local agencies began a pilot investigation to characterize mercury distribution, transport, and fate in the Bear River and South Yuba River watersheds, California. This information will be useful in establishing management priorities for abandoned mines in these watersheds. We collected game fish from 5 reservoir sites and 17 stream sites during August through October 1999 to assess the distribution of mercury in the food chain and to examine the potential risk for humans and wildlife. Fillets from 161 fish were analyzed for total mercury; 131 were analyzed as individuals and the remaining 30 were analyzed as 10 composites of three fish of the same species and size class. Of the samples analyzed, 29 percent contained greater than 0.5 parts per million (ppm), wet weight total mercury. Mercury concentrations exceeded 1.0 ppm-the FDA action level-in 14 percent of the samples of bass (*Micropterus* sp.). Sixty-five percent of the bass contained concentrations greater than 0.5 ppm total mercury. Mercury at such elevated concentrations may pose a health risk to piscivorous wildlife. In addition, similar concentrations of mercury have merited various levels of fish consumption advisories elsewhere in California and in other states.

INTER-ANNUAL VARIATION OF SEDIMENT SUPPLY FROM LOCAL WATERSHEDS ENTERING SAN PABLO BAY

Lester J. McKee*

San Francisco Estuary Institute, 180 Richmond Field Station, 1325 South 46th Street, Richmond, CA 94804, Phone: 510-231-9578, Fax: 510-231-9414, e-mail: lester@sfei.org

Deposition of suspended sediment in the lower reaches of rivers and the receiving waters of San Pablo Bay will vary annually and will have effect substrate grainsize and the transport of sediment bound pollutants. An important need of San Pablo Bay environmental management and the TMDL process is a recognition of the fluvial variability of local watersheds. How much eroded sediment is discharged on an annual basis to San Pablo Bay from local watersheds and what is the inter-annual variability? Does an annual average adequately describe the fluvial process in the context of management or are the extremes in the systems more important for habitat and water quality? Water discharge from the Napa River at St. Helena, for example, varies on an annual basis from 2 to 241 ML/yr or about 142 times (56 years of data). In the case of Wildcat Creek watershed, discharge varies on an annual basis from 0.4 to 14 ML/yr or about 35 times (19 years of data). Research in other parts of the world suggest that sediment transport in hydrologically variable systems is much more variable that water discharge due to both supply of eroded sediment, antecedent conditions and flow competency. For instance, annual flow in the sub-tropical Richmond River watershed, Australia varies by 29 times and suspended sediment discharge varies by 931 times (14 years of data). It is postulated that variability of sediment loads entering San Pablo Bay from local watershed is likely to vary by a similar or greater magnitude as systems in other parts of the world due to higher discharge variability. Preliminary analysis of temporally limited of local suspended sediment data sets support this theory.

EXPOSURE OF DELTA SMELT TO DISSOLVED PESTICIDES DURING LARVAL AND JUVENILE STAGES IN 1998 AND 1999

G. Edward Moon, K.M. Kuivila, and J.L. Orlando

U.S. Geological Survey, Placer Hall, 6000 J Street, Sacramento, CA 95819-6129
Phone: 916-278-3060, Fax: 916-278-3071, e-mail: gemoon@usgs.gov

The cause(s) of the decline of delta smelt abundance in San Francisco Bay Estuary since 1983 are not known. One possible factor is pesticide toxicity during vulnerable larval and juvenile stages, but the concentrations of pesticides are not well characterized in delta smelt spawning and nursery habitat. The objective of this study was to quantify the exposure of delta smelt to dissolved pesticides during these sensitive life stages. Water samples were analyzed for pesticides from two major spawning areas (northwestern and central Sacramento-San Joaquin Delta) and one nursery area (Suisun Bay) during the spring and summer of 1998 and 1999. The two spawning areas are closer to sources of pesticides than the nursery area is and, as would be expected, more pesticides were detected at higher concentrations in the spawning areas. Pesticides detected included carbaryl, carbofuran, diazinon, eptam, metolachlor, molinate, simazine, sulfotep, thiobenbarb, and trifluralin with maximum concentrations ranging from 0.46 to 7.7 mg/L. Although these concentrations are well below LC50 values for the individual pesticides, the combination of multiple pesticides could potentially cause sublethal effects on the delta smelt, especially during the early larval development. In addition, the duration of exposure to elevated pesticide concentrations was weeks to months, whereas most toxicity testing is conducted only for days to weeks. In a concurrent field study, University of California at Davis (UCD) scientists are measuring biomarkers, histopathology, DNA fragmentation, and growth rates of delta smelt. The exposure results from this study will be related to the effects observed in the UCD study.

METHODS FOR DETERMINATION OF AGROCHEMICALS IN THE INVASIVE ASIAN CLAM (*POTAMOCORBULA AMURENSIS*) FROM SAN FRANCISCO BAY

Carl E. Orazio[*1], R.W. Gale[1], J.C. Meadows[1], and K.M. Kuivila[2]

[1]**Columbia Environmental Research Center, U.S. Geological Survey, 4299 New Haven Road, Columbia, MO 65201, Phone: 573-875-5399, Fax: 573-876-1896, e-mail: Carl_Orazio@usgs.gov**

[2]**U.S. Geological Survey, Placer Hall, 6000 J Street Sacramento, CA 95819**

A number of agricultural and industrial chemicals potentially impact the health of the San Francisco Bay ecosystem. While analytical methods for agrochemicals in water are readily available, methods for agrochemicals in biota are sparse and no screening method is widely applicable. We selected 15 high-use chemicals, representing several pesticide classes and covering a wide range of hydrophobicities for developing a simple, broad-based screening method to complement those for organochlorine pesticides, PCBs, and PAHs in tissue.

A dominant benthic species in the bay, the invasive Asian clam (Potamocorbula amurensis) is both a significant food source for fish such as the green sturgeon and diving ducks and, potentially, a significant source of contaminants for biomagnification. The Asian clam is known to concentrate selenium, but its potential to bioaccumulate organic pollutants has not been investigated. Our objective is to select suites of industrial and agricultural chemicals, develop the analytical methods for their analysis in tissue, and investigate changes in pesticide concentrations over time. This will complement current water and sediment residue information.

The chemical properties of the selected agrochemicals indicate that tissue concentrations may be in the low parts-per-trillion. The presence of multiple classes of chemicals at low concentrations, combined with very low lipid content and the availability of only small quantities of highly pigmented tissue, present a considerable analytical challenge requiring high selectivity and sensitivity. Separate and lengthy analytical methods for each class of pesticides are prohibitive. We have investigated fractionation schemes using Florisil®, alumina, silica gel and modified silica gels, reverse-phase sorbents, and high performance gel-permeation chromatography to produce purified and concentrated extracts for gas chromatography with mass spectrometric and electron-capture detection. Concentrations of PCBs, organochlorine pesticides, and PAHs in Asian clams, collected monthly from Susiun Bay during 1999, will be presented, as will the current state of the multi-class method for agrochemicals.

FACTORS CONTROLLING LOADS OF DIAZINON AND METHIDATHION IN THE SACRAMENTO AND SAN JOAQUIN RIVERS, 1992–1994

James L. Orlando* and K.M. Kuivila

U.S. Geological Survey, 6000 J Street, Sacramento, CA 95819-6129
Phone: 916-278-3271, Fax: 916-278-3071, e-mail: jorlando@usgs.gov

Pulses of dormant spray insecticides are detected each winter in the Sacramento and San Joaquin Rivers following application on orchards and subsequent rainfall. The biological effects of these organophosphate insecticides are of environmental concern, due to their potentially lethal effects on aquatic invertebrates. The objective of this study was the identification of factors controlling runoff and transport of two dormant spray pesticides, diazinon and methidathion, by comparing the calculated loads within the Sacramento and San Joaquin River Basins from three hydrologically different years. Pesticide concentration data were collected from 1992 to 1994 by the U.S. Geological Survey's San Francisco Bay Estuary Toxic Substances Hydrology Project. Water samples were taken frequently (from three times per week to twice a day) at two sites, Tower Bridge on the Sacramento River, and Vernalis on the San Joaquin River, and analyzed for dissolved pesticides. Total pesticide loads were calculated by multiplying the instantaneous measured pesticide concentrations by the instantaneous discharge and integrating over the dormant spray season.

Yearly comparison of diazinon loads showed variations by as much as an order of magnitude, with the largest loads occurring in both basins in 1993. Comparing basin to basin, diazinon loads were higher for the Sacramento River watershed than for the San Joaquin River watershed from 1992 to 1994. In contrast, methidathion loads varied, with no obvious patterns between basins from 1992 to 1994.

Pesticide loads can be influenced by several factors. Variations in pesticide application amounts do not explain the observed trends in pesticide loads. The annual variability in pesticide loads may be explained by the relation between diazinon application, and the timing, amount, and location of rainfall. Basin-to-basin differences may be explained by differences in such characteristics as soil types and the hydrologic connection between the orchards and the river.

PHYSICAL PROCESSES IN TIDAL WETLANDS OF THE SACRAMENTO-SAN JOAQUIN ESTUARY AND THEIR IMPLICATIONS FOR PROPOSED RESTORATION

Michelle K. Orr* and P.B. Williams

Philip Williams & Associates, 770 Tamalpais Drive, Suite 401, Corte Madera, CA 94925
Phone: 415-945-0600, Fax: 415-945-0606, e-mail: mko@pwa-ltd.com

A review of existing scientific literature was used to assess two key questions related to tidal wetland restoration in the San Francisco Estuary: 1) will the ecosystem benefits of restoring tidal wetlands be sustainable?; and 2) will existing wetland habitat be impacted by hydrodynamic changes associated with tidal wetland restoration in the Delta? In response to Question 1, experience with restored and re-flooded sites in the Estuary indicates that the ecological benefits of restored vegetated tidal marsh are likely to be sustainable in response to on-going physical processes. Once vegetation establishes, restored marsh is unlikely to revert to mudflat or open water, although the edges of the marsh may erode due to wave action. Restored slough channels will be sustained by natural tidal scour and deposition. Artificially constructed marsh ponds and pannes may not be sustainable, but are expected to form on their own as the marsh matures. In response to Question 2, the hydrodynamic effects of restoring vegetated tidal marsh in the Delta depend on how and where the restoration occurs. Compared to existing conditions, using fill and levee breaching to restore vegetated tidal marsh in currently leveed areas will generally increase inland salinity migration and tidal scour while using fill to restore areas that are currently flooded will have the opposite effects. Inland salinity migration would increase the relative extents of salt and brackish marsh within the Estuary and possibly affect the location of the entrapment zone. Increased tidal scour could cause localized loss of channel fringing marsh. Compared to expected future conditions, restoring vegetated tidal marsh in the Delta could be critical in the long-term for avoiding the effects of permanent levee abandonment. Levee abandonment would create large areas of open water and cause significant inland salinity migration, tidal scour, and alteration to the Estuary's sediment budget.

TIDAL MARSH INDICATORS: APPLYING WHAT WE KNOW FROM OTHER SYSTEMS

Anitra L. Pawley*

The Bay Institute, 709 N Street, Davis, CA 95616
Phone: 530-758-4558, Fax: 530-758-4558, e-mail: pawley@bay.org

One of CALFED's primary program objectives is to "Restore large expanses of all major habitat types, and sufficient connectivity among habitats, in the Delta, Suisun Bay, Suisun Marsh, and San Francisco Bay to support recovery and restoration of native species and biotic communities and rehabilitation of ecological processes. These habitat types include tidal marsh (fresh, brackish, and saline)..." Already, numerous tidal marsh restoration projects have been proposed, funded or started with this intent; however it is unclear how the CALFED Ecosystem Restoration Program will determine to what extent this goal has been satisfied and to what extent "functional" tidal marsh has been restored. As a first step toward identifying indicators of functional tidal marsh, I have reviewed the literature on tidal marsh restoration and mitigation projects, to evaluate which variables and/or indicators were most useful for determining project/program performance. The review of these parameters is presented, and includes hydrologic, geomorphic processes, habitat structure, biotic community response, and composite measures proposed to synthesize these processes. With this review and knowledge of the literature on Bay-Delta tidal marsh processes, I propose a draft "suite" of indicators to evaluate tidal marsh ecosystem health in the CALFED Bay-Delta system.

INDICATORS DEVELOPMENT FRAMEWORK AND PROPOSED PROGRAM-WIDE INDICATORS FOR THE CALFED ECOSYSTEM RESTORATION PROGRAM

Anitra L. Pawley*

The Bay Institute, 709 N Street, Davis, CA 95616
Phone: 530-758-4558, Fax: 530-758-4558, e-mail: pawley@bay.org

Large scale regional restoration planning is a relatively recent phenomenon. Although the need to objectively evaluate and monitor the success of such efforts is widely recognized, as yet no widely-accepted, unified framework exists for developing appropriate program performance indicators for large-scale, comprehensive ecological restoration efforts (Harwell 1999). At the least, it has been suggested that such indicators should encompass a wide array of inherent ecological attributes and system stressors; multiple lines of evidence must be examined to properly evaluate changes in ecological integrity as well as program/project success (Noss 1990). Most large scale ecological restoration and management programs choose multiple indicators or a "suite of indicators" in the form of a "report card" to demonstrate how actions affect ecosystem structure, processes and associated stressors. Program performance indicators, in this sense, are indicators to be used at the program-wide level to: evaluate environmental response to restoration/ management efforts, inform the adaptive management process, provide information designed to facilitate management decisions and inform the public of restoration progress.

In November 1999, the ERP Performance Indicators Coordination Team was convened for the purpose of developing a Program Performance Indicators Development Process and a recommended suite of performance indicators for the CALFED Ecosystem Restoration program. We summarize the process developed to accomplish this task, and a list of proposed program-wide performance indicators intended to assess and review the extent to which CALFED's goals and objectives have been achieved over both short (1-7 years) and long term timescales (7 years).

SOURCES AND REACTIVITY OF ORGANIC MATTER IN SHALLOW-WATER HABITATS IN THE SACRAMENTO-SAN JOAQUIN RIVER DELTA

Vicki L. Pilon*, E.A. Canuel, and M.E. Hagy

The Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, VA 23062, Phone: 804-684-7439, Fax: 804-684-7786, e-mail: vpilon@vims.edu

One of the rehabilitation actions proposed for the Sacramento-San Joaquin River Delta is to increase shallow-water habitats. These habitats may act as favorable habitat for fish species due to higher food availability. The increase in the availability of labile organic matter resulting from the expansion of these is expected to contribute to subsequent increases in secondary production. However, little is known about the sources of organic matter in these important habitats, or its potential usefulness to secondary producers.

In this study, two classes of lipid biomarker compounds are being used to determine temporal variations in both sources and relative lability of organic matter for 3 shallow-water habitats in the Delta (Mildred Island, Franks Tract, Little Holland Tract) for one year (1998-1999). Stable isotopes (carbon and nitrogen), and bulk biochemical analyses (total proteins, carbohydrates, lipids) are also being utilized to assess the potential usefulness of POM.

Preliminary results indicate that in Mildred Island, plants made up 33-36% of sources to the system from October 1998-1999, phytoplankton 13-18%, and crustacean sources 24-34%. However, at MI-Southeast Cove in October 1999, phytoplankton sources were dominant, accounting for 36% of all sources. Polyunsaturated fatty acid (PUFA) concentrations remained relatively constant from October 1998 to 1999, with values of 3-8 mg PUFA/mg OC. However, variability within this site was high; concentrations in October 1998 were 5 mg/mg OC at MI-3, and 56 mg/mg OC at site MI-1. This indicates that phytoplankton material was abundant and highly labile at this sub-site of Mildred Island. These results indicate that although shallow-water habitats may produce more labile organic matter, this production is not homogeneously distributed throughout each shallow-water system. Results will also be presented for Franks Tract and Little Holland Tract, which are two other shallow-water sites in the Delta.

SEASONAL AND TEMPORAL TRENDS OF ZOOPLANKTON SELENIUM CONCENTRATIONS IN SAN FRANCISCO BAY

David G. Purkerson[*1], M.A. Doblin[2], S.N. Luoma[3], S.M. Bollens[1], and G.A. Cutter[2]

[1]**Romberg Tiburon Center for Environmental Studies and Department of Biology, San Francisco State University, San Francisco, CA 94132, Phone: 415-338-3517, e-mail: purkerso@sfsu.edu**

[2]**Dept. of Ocean, Earth and Atmospheric Science, Old Dominion University, Norfolk, VA 23529**

[3]**U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025**

The potential toxicity of elevated selenium concentrations in San Francisco Bay has stimulated efforts to measure selenium concentrations in benthos, nekton and waterfowl. In August 1998, we initiated a field study to determine the concentration of selenium (Se) in San Francisco Bay (SFB) zooplankton. This study is the first to quantify concentrations in zooplankton, which play a major role in the food web of the bay. Our specific goals were to determine effects of flow regime (high vs. low freshwater flow) and proximity to sources (e.g. oil refineries and agricultural run-off) on spatial and temporal variations in zooplankton Se concentrations in North SFB. Monthly vertical plankton tows were collected at several stations using a 73 µm mesh ring net. Zooplankton samples were immediately separated into four operationally-defined size classes: 73 to 250 µm, 250 to 500 µm, 500 to 2000 µm, and 2000 µm. Samples were left to depurate for two hours prior to freezing, and selenium concentrations were subsequently determined by atomic absorption spectroscopy. Based on thirteen months of samples analyzed thus far, concentrations ranged from 0.45 (m)g Se. g-1 dry weight up to 6.07 (m)g Se. g-1 dry weight. There were no significant spatial differences found in zooplankton Se concentrations. There were also no significant differences in Se concentrations between the two smallest size classes (73 to 250 and 250 to 500 µm), but the smaller zooplankton (73 to 500 µm) had significantly higher Se concentrations than the largest size class (2000 µm). In 1999, Se concentrations were significantly higher in North SFB during fall compared to spring, indicating a possible increase in zooplankton Se concentration as Delta outflow is lowest and residence time increased.

SOFTWARE DEMONSTRATION, INDIVIDUAL-BASED CHINOOK SALMON MODEL FOR THE SACRAMENTO RIVER

Steven F. Railsback[*1] and S. Jackson[2]

[1]**Lang, Railsback and Assoc., 250 California Ave., Arcata, CA 95521**
Phone: 707-822-0453, Fax: 707-822-1868, e-mail: LRA@Northcoast.com

[2]**Jackson Scientific Computing, McKinleyville, CA**

The Sacramento River chinook model is an individual-based simulator of habitat and salmon in the Sacramento watershed, San Francisco bay and estuary, and Pacific ocean. The model simulates individual salmon through the full life cycle of four stages: upstream migration, spawning and incubation, juvenile development and emigration, and ocean. Key processes modeled are survival, feeding and growth, habitat choice, and timing of life history events like smolting, migration, and spawning. We are implementing this model in software that (1) provides graphical interfaces allowing individual fish and habitat units to be observed; (2) simulates different life stages at different spatial and temporal resolutions; (3) allows simulations to be initialized with adult migrants and/or newly emerged juveniles; (4) allows separate parameter values and methods for each of the four chinook races; and (5) is highly modular and adaptable so changes can be made with minimal effort and risk of introducing errors. These features of the model software will be demonstrated.

HORIZONTAL AND VERTICAL DISTRIBUTION OF LARVAL DELTA SMELT

Andrew K. Rockriver*

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-948-7725, Fax: 209-946-6355, e-mail: arockriv@delta.dfg.ca.gov

Little information exists on the vertical and horizontal distribution of larval delta smelt. During the spring of 1997 and 1998, 4 plankton nets were mounted on a pushnet frame and used to sample shallow water habitats in the Sacramento-San Joaquin Delta and San Francisco Estuary. Early this year, 3 conical plankton nets were fished in the channel of the San Joaquin River to determine the day-night vertical distribution of larval smelt. Approximately 71% of the 1600 samples collected between 1997 and 1998 contained no delta smelt and only 8% had more than 5 delta smelt. When larval delta smelt were caught in relatively large numbers, more fish were caught in the surface nets than the bottom nets. Surface densities varied among channel, shallow and shore habitats. Unfortunately, few smelt larvae were caught during the day-night vertical distribution study. Preliminary results from this study suggest smelt were more abundant at the mid-depth than at the surface or bottom. There appears to be no difference in catch between flood and ebb tides; however, more than three times as many smelt were caught at night than in the day. Although the experimental gear used in these studies appeared to work well, delta smelt were rarely caught in large numbers. The sporadic catches were probably due to the timing, patchy distribution, and variable densities of larval delta smelt.

DIEL PATTERNS OF NANO- AND MICRO-PLANKTON VERTICAL DISTRIBUTION IN SOUTH SAN FRANCISCO BAY

Gretchen Rollwagen-Bollens[*] and D.L. Penry

Dept. of Integrative Biology, University of California, Berkeley, 3060 VLSB, Berkeley, CA 94720
Phone: 510-642-8690, Fax: 510-643-6264, e-mail: grollwag@socrates.berkeley.edu

Acartia spp. copepods are among the dominant mesozooplankton taxa in the saline (10 psu) reaches of San Francisco Bay (SFB). *Acartia* generally consume prey between about 5 and 30 microns in diameter (spanning the nano- and microplankton) and are known to be omnivorous on autotrophic and heterotrophic prey in many estuaries, including SFB. In addition to their omnivorous feeding behavior, Acartia and many other estuarine copepods often show diel (day/night) differences in their vertical distribution. Over a two-year period we measured the vertical distributions of nanoplankton (5 to 20 microns) and microplankton (20 to 200 microns) in SFB in order to determine diel patterns, seasonal differences and their potential relationship to predator distribution.

Between November 1997 and August 1999 replicate daytime and nighttime water samples from five depths were taken quarterly in South San Francisco Bay. Subsamples were analyzed for microplankton and nanoplankton composition, abundance and biomass. The 1998 El Niño brought heavy winter precipitation to the Bay area, resulting in strong density stratification in South Bay and a significantly higher than average spring phytoplankton bloom. Mean nano- and microplankton biomass was also significantly higher during the El Niño bloom season than the following year's bloom, while summer dry season biomass levels were consistently low each year. Differences in day and night vertical distributions of nano- and microplankton showed variability related to both bloom vs. non-bloom conditions and the intensity of bloom periods.

ECOLOGY, DISTRIBUTION AND IMPACTS OF THE CHINESE MITTEN CRAB (*ERIOCHEIR SINENSIS*) IN SAN FRANCISCO BAY

Deborah A. Rudnick*, L.A. Rogers, and V.H. Resh

Department of Environmental Science, Policy and Management, University of California, Berkeley, 201 Wellman Hall, Berkeley, CA 94720, Phone: 510-642-6315, Fax: 510-642-7428, e-mail: drudnick@nature.berkeley.edu

The Chinese mitten crab, *Eriocheir sinensis*, is a recent arrival to the San Francisco Bay ecosystem. Despite serious concerns in California about its potential for ecological and economic impacts, little is known about the ecology of this freshwater, catadromous crab. We are initiating a study to examine the ecology, distribution, and ecological and economic impacts of the Chinese mitten crab in the Bay/Delta ecosystem. Our objectives are to: 1) monitor distribution and abundance of the mitten crab in South San Francisco Bay; 2) examine habitat associations of the crab; 3) quantify impacts to banks and levees resulting from the crabs' burrowing activities; 4) elucidate the trophic ecology of the mitten crab in its new environment; and 5) explore the impacts of the mitten crab on commercially valuable species such as freshwater crayfish. Preliminary results from our research include that this species is already widespread in the tributaries and open waters of the South Bay. The highest burrow densities occur along steep, vegetated, tidally influenced banks of tributaries to the Bay; densities are high enough in some areas to contribute to significant bank weakening and erosion. Gut content analysis indicates crabs are mostly feeding on algae and detritus, whereas laboratory feeding preference experiments suggest the crab may preferentially consume aquatic invertebrates if they are available. Field observation shows that mitten crabs and freshwater crayfish co-occur, but pilot behavioral studies suggest that mitten crabs, particularly males, may be superior competitors for shelter than are freshwater crayfish. Our preliminary results indicate that, given its large population size, widespread distribution, and opportunistic feeding characteristics, the mitten crab can effect widespread changes in its new ecosystem. In our ongoing research, we will quantify these effects in order to elucidate the mitten crab's role in the aquatic communities of the San Francisco Bay-Delta and its watersheds.

SPATIAL AND SEASONAL VARIABILITY OF SUSPENDED-SEDIMENT CONCENTRATIONS IN HONKERBAY, A SHALLOW SUBEMBAYMENT OF SAN FRANCISCO BAY

Catherine A. Ruhl[*] and D.H. Schoellhamer

U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA 95819
Phone: 916-278-3122, e-mail: caruhl@usgs.gov

San Francisco Bay includes extensive areas of shallow water, with approximately one-half of its surface area being less than 2 meters deep. Shallow environments are ecologically significant and a large fraction of estuarine biota depends on these areas for shelter and nourishment. The deeper channels along the spine of the Bay, however, are sampled most regularly for physical, chemical, and biological parameters. In order to investigate the differences between shallow-water areas and deep-water channels, Honker Bay and the neighboring channel were chosen to investigate the spatial and temporal variability of suspended sediments. These suspended sediments are an important component of the estuarine environment harboring a nutrient supply, impacting light penetration through the water column, and adsorbing potential contaminants.

Time series of suspended-sediment concentration (SSC) were measured at several sites in Honker Bay from December 1996 to August 1997. We made three primary observations based on this data set: 1) Honker Bay acted as a temporary storage zone for flood-derived sediments during the winter rainy season causing extended periods of elevated SSC in the shallow-water areas as compared to the neighboring channels; 2) wind-waves in the early spring resuspended unconsolidated-fine sediments and caused the greatest spatial variability of SSC within Honker Bay; and 3) reduced SSC was observed in the summer, even though wind-waves persisted, due to the earlier winnowing of fine sediments causing limited availability of erodible sediments.

The spatial and seasonal patterns of SSC variability observed in our data set indicates that shallow estuarine environments such as Honker Bay respond differently to physical forces than the deeper channel environments along the spine of San Francisco Bay.

CONDITION INDICES OF LARVAL PACIFIC HERRING (*CLUPEA PALLASI*) IN THE SAN FRANCISCO ESTUARY

Alison M. Sanders*, S.M. Bollens, and T.M. Johnson

Romberg Tiburon Center and Department of Biology, San Francisco State University, 3152 Paradise Drive, Tiburon, CA 94920, Phone: 415-338-3511, Fax: 415-435-7121, e-mail: asanders@sfsu.edu

The short-term objective of this research is to determine the "nutritional" condition of larval Pacific herring (*Clupea pallasi*) in San Francisco Bay using various morphometric characters. Our longer-term objective is to relate variation in larval herring condition to variation in other physical (e.g., temperature, salinity) and biological (e.g., copepod prey) variables, and to evaluate the larvae's utility as ecological indicators of ecosystem condition or status. Two sites in San Francisco Bay (San Pablo Bay and Central Bay) were sampled each month from November 1999 through May 2000. Duplicate or triplicate nighttime, water column total hauls were made at each station with a 1 m^2/500 µm mesh Tucker trawl. A total of 562 herring larvae were sorted, identified and measured. For each larva, six morphometric characters were measured; three (anal body depth, pectoral body depth, and dry weight) that are sensitive to growth (food) and three (eye diameter, standard length, and head width) that are relatively insensitive to growth (food). From these six measurements we derived nine potential indices of condition by dividing each "food sensitive" measurement (e.g., body weight) by each "food insensitive" measurement (e.g., eye diameter). All morphometric measurements increased between November and May, indicating larval growth, but none were significantly different between locations ($P < 0.001$). All condition indices also changed with season, with a larger proportion of fish having higher values later in the season (e.g., late March), suggesting "better" larval condition at this time. Chlorophyll biomass and copepod egg production showed similar patterns of variation as the larval herring condition indices, suggesting the importance of trophic linkages. Our future research will focus on better understanding the causal mechanisms underlying larval herring condition, as well as evaluating the utility of these indices as indicators of ecosystem condition or status.

NUTRIENTS AND EVIDENCE OF ALGAL PRODUCTION IN THE YOLO BYPASS: WINTER AND SPRING 2000

Laurence E. Schemel[*1], S.W. Hager[1], M.H.Cox[1], W.V. Sobczak[1], and A.B. Mueller-Solger[2]

[1]**U.S.Geological Survey, Water Resources Division, 345 Middlefield Road, Menlo Park, CA 94025, Phone: 650-329-4436, Fax: 650-329-4327, e-mail: lschemel@usgs.gov**

[2]**Department of Environmental Science and Policy, University of California, Davis, CA 95616**

Concentrations of dissolved nutrients and particulate carbon and nitrogen were measured in the Yolo Bypass floodplain and in streams that discharge into the west side of the floodplain as part of a study to identify factors that might enhance the quality of this seasonal habitat for fish. When floodwaters from the Sacramento River inundated the floodplain from mid-February to mid-March, dissolved reactive phosphate (DRP) and dissolved inorganic nitrogen (nitrate, nitrite, and ammonium; DIN) were low and dissolved silica (DSi) and particle C:N ratios were high in the Yolo Bypass. The west-side streams became major sources of freshwater to the Yolo Bypass when spillage from the Sacramento River stopped in mid-March and the floodplain began to drain. Samples collected along the eastern margin of the Yolo Bypass, the deeper side of the floodplain, showed a rapid decrease in DSi and increases in DRP and DIN. These changes could be explained, in part, by inflows from the streams and by algal production in the DIN- and DRP-rich water. Particulate carbon and chlorophyll a increased, and C:N ratios were low during the draining period. In mid-April a small storm increased discharges from the creeks, briefly increasing flow along the eastern margin of the floodplain to the western Delta. The above results indicate that the draining period in the Yolo Bypass might provide a particularly valuable fish habitat because of abundant nutrients and algal production. In addition, the Yolo Bypass might influence downstream habitats because nutrients and algae can be supplied to the western Delta during the initial draining period and subsequent discharge events.

DIETARY SELENIUM UPTAKE AMONG DIFFERENT FOOD WEBS IN SAN FRANCISCO BAY

Christian E. Schlekat[*1], D.G. Purkerson[2], B.G. Lee[1], and S.N. Luoma[1]

[1]**U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025**
Phone: 650-329-4713, Fax: 650-329-4545, e-mail: cschleka@usgs.gov

[2]**San Francisco State University, Department of Biology, Tiburon, CA 94920**

The main process by which upper trophic level wildlife (e.g., wildfowl and fish) are exposed to selenium is through their diet. We compared the processes controlling trophic transfer of selenium between benthic and water column organisms from San Francisco Bay (SFB) to determine if there were broad scale differences in these two food webs. Selenium assimilation efficiency (AE) by benthic organisms, including filter-feeding bivalves (*Macoma balthica* and *Potamocorbula amurensis*) and amphipods (*Leptocheirus plumulosus*), was determined from five species of phytoplankton. Assimilation of Se by clams (58.0 ± 3.2 to 92.3 ± 6.0%) was greater than by amphipods (32.1 ± 1.8 to 69.5 ± 7.1%). Se AE by *M. balthica* varied according to the proportion of Se within the cytoplasm of algal cells, but *P. amurensis* assimilated non-cytoplasmic Se as well (the mechanism is not yet clear). A high basal assimilation from all food sources may explain unusually elevated tissue Se concentrations exhibited by *P. amurensis* in SFB. Among the water column species, Se AE by carnivorous mysid shrimp was measured from assemblages of large (230 to 500 µm) and small (73 to 230 µm) zooplankton from SFB. Mysids assimilated between 54 and 62% of Se from large zooplankton; Se AE was significantly higher (72%) from smaller zooplankton. Both zooplankton assemblages assimilated Se with similar efficiency (67% to 72%) from phytoplankton. Se depuration rates, which affect steady state Se concentrations, were higher for zooplankton and mysids (12% to 25% d^{-1}) than bivalves (2% to 3% d^{-1}). Se transfer to upper trophic level wildlife may be efficient in bivalve-based food webs when bivalves assimilate most of the Se they ingest and lose the element slowly. Se transfer in pelagic food webs may be short-circuited because zooplankton and mysids assimilate Se efficiently but lose it rapidly.

WATER QUALITY OF SAN FRANCISCO BAY WEBSITE: A 30-YEAR HISTORICAL DATABASE

Tara S. Schraga*, J.E. Cloern, B.E. Cole, J.L. Edmunds, and A. Arnsberg

U.S. Geological Survey, 345 Middlefield Road, MS-496, Menlo Park, CA 94025
Phone: 650-329-4381, Fax: 650-329-4327, e-mail: tschraga@usgs.gov

For over three decades the U.S. Geological Survey has researched phytoplankton and water quality dynamics in San Francisco Bay and maintained the longest continuous program of water quality monitoring in a United States estuary. Water quality descriptors, including chlorophyll, dissolved oxygen, salinity, and suspended particulate matter, have been measured along a 150 kilometer transect from the South Bay into the Sacramento River, thus spanning the length of the entire estuarine system.

The USGS Water Quality of San Francisco Bay website describes this measurement program and allows public access to the data. The results of each sampling cruise are posted using dynamic color graphics, enabling users to visualize water quality patterns in the Bay. In addition, the data query section of the website allows users to selectively extract, tabulate, and download specific subsets of the 30-year data set. This user-configurable on-line database is regularly used by citizens, teachers, researchers and resource managers from around the world. This long-term data set is available to all CALFED researchers, managers, stakeholders and conference participants. We invite everyone to learn more about this website and our ecosystem research program.

THE DISTRIBUTION AND EFFECTS OF SELECTED NONNATIVE INVASIVE SPECIES OF THE SAN FRANCISCO ESTUARY

Mary L. Sommer*

California Department of Fish and Game, 4001 N. Wilson Way, Stockton, CA 95205
Phone: 209-942-6076, Fax: 209-946-6355, e-mail: msommer@delta.dfg.ca.gov

The introduction rate of nonnative invasive species (NIS) in the San Francisco Bay and Delta has increased dramatically in recent decades, and the cumulative effect of these introduced species on the ecosystem has become substantial. The San Francisco Bay and Delta may now be considered the most invaded aquatic ecosystem in North America. For this poster, distribution maps of existing NIS were created using a Geographical Information System (GIS), and potential distribution of possible NIS invasions were determined using physiological tolerance, habitat preferences and other known factors as guidelines. The poster contains maps showing current and potential distribution for various NIS, and shows the primary known impacts to the native ecosystem.

FLOODPLAIN AS A SOURCE OF PHYTOPLANKTON FOR THE SAN FRANCISCO ESTUARY

Ted R. Sommer[*1], A. Mueller-Solger[2], B. Harrell[1], W. Batham[1], and R. Kurth[1]

[1]**California Department of Water Resources, 3251 S Street, Sacramento, CA 95816**
Phone: 916-227-7537, Fax: 916-227-7554, e-mail: tsommer@water.ca.gov

[2]**University of California, Davis, CA 95616**

Export of phytoplankton has been suggested for natural floodplain systems, although there is little evidence to support this phenomenon. During 1998-1999 we observed peaks in chlorophyll at Rio Vista coincident with the draining of the upstream Yolo Bypass floodplain, the largest floodplain in the San Francisco Estuary. In 2000 we conducted studies to determine whether this 24,000 ha engineered floodplain was a net source of phytoplankton. Before the floodplain was inundated, chlorophyll levels were higher in the tidally-influenced perennial channel (Toe Drain) of the Yolo Bypass than in the adjacent Sacramento River. However, chlorophyll levels were relatively low in the two locations during the primary period of floodplain inundation, mid-February to mid-March. Yolo Bypass chlorophyll levels increased rapidly during drainage, demonstrating that the floodplain was a net source of phytoplankton. We attribute this production to longer residence time, shallower depths and greater surface area in the floodplain than the adjacent river channel. These results suggest that floodplain restoration can help meet CALFED lower trophic level objectives.

USING SEEPAGE METERS AND THERMAL GRADIENTS TO QUANTIFY GROUNDWATER FLUXES IN THE LOWER COSUMNES RIVER BASIN

Eriko Suzuki*, J. Fleckenstein, G.E. Fogg

Land, Air and Water Resources—Hydrologic Sciences, University of California, Davis, 1 Shields Ave., Davis, CA 95616, Phone: 530-752-1372, e-mail: exsuzuki@ucdavis.edu

Upstream migration of the chinook salmon in the Cosumnes River is inhibited by the cessation of streamflow in the fall. Seepage losses in the summer months and the over appropriation of the stream are the major factors contributing to the lack of fall streamflow. Although the regional groundwater level is substantially lower than the streambed, previous seepage meter measurements have indicated upward seepage following the wet winter season, suggesting contributions from perched aquifers. Measurements and estimates of vertical groundwater flow across the streambed based on seepage meter and thermal gradient methods can elucidate seasonal groundwater movement and interactions with surface water. Local scale influence of shallow groundwater on streamflow will aid in establishing sufficient and sustainable fall run conditions.

Although the seepage meters produced results that varied, measurements taken during June 1999 to August 1999 suggest seepage fluxes in the range of 0.014 to 0.85 mm/s. One site showed an upward flux in the range of 0.42 to 0.79 mm/s. Measurements based on seepage meters during late spring through summer 2000 will be shown. Temperature gradients between the stream and the underlying sediments are sensitive indicators of upward or downward seepage. Using a coupled groundwater and heat flow model, groundwater fluxes can be estimated. Preliminary results of the thermal gradients between the stream and the underlying sediments and analysis will also be shown.

MOKELUMNE RIVER CHINOOK SALMON FRY OUTMIGRATION PILOT STUDY

Tom L. Taylor[*1], S. Cramer[2], and D. Demko[2]

[1]**Entrix, Inc., 2601 Fair Oaks Blvd., Suite 200, Sacramento, CA 95864**
Phone: 916-923-1097, Fax: 916-923-6251, e-mail: ttaylor@entrix.com
[2]**S.P. Cramer & Associates, 300 S.E. Arrow Creek Lane, Gresham, OR 97080**

A pilot study designed to develop collection techniques and collect basic information on fall-run chinook salmon fry, *Oncorhynchus tshawytscha*, emigrating from the Lower Mokelumne River was conducted in late winter and early spring of 2000. Collection methods and techniques were tested and information on distribution, abundance, habitat use and growth was collected during the study. Boat and backpack electrofishing, seining and trapping methods were evaluated in the study. Boat electrofishing was more suitable for the steep-sided banks dominating a majority of the study area, however, where beaches were present, seining was more effective at catching salmon. Backpack electrofishing was suitable for sampling small areas of inundated flood plain. A distinct fry emigration occurred in mid-February from the Lower Mokelumne River as documented by RST captures at Woodbridge Dam. Juvenile salmon were collected during the study period from late February to early April, throughout the western Mokelumne River from near Woodbridge Dam down to the confluence with the San Joaquin River in the Sacramento-San Joaquin Delta. Juvenile salmon were found in varying abundance and in a variety of habitats. Habitat use in both the riverine and tidally dominated areas seemed to be more associated with localized hydraulic conditions than the presence of physical structure. Average fish size increased during the study period. It appears from information gathered during the pilot study that fry emigrants continue to move downstream, growing as they go. Catches were evaluated in regard to habitat, water temperature, turbidity and streamflow.

SUBLETHAL TOXICITY OF ESFENVALERATE AND DIAZINON TO SACRAMENTO SPLITTAIL (*POGONICHTHYS MACROLEPIDOTUS*) LARVAE

Swee Teh[*1], D.F. Deng[2], I. Werner[1], F.C. Teh[1], and S.S.O. Hung[2]

[1]**Dept. of Anatomy, Cell Biology, and Physiology, School of Veterinary Medicine, 1321 Haring Hall, University of California, Davis, CA 95616, Phone: 530-754-8183, Fax: 530-754-7788, e-mail: sjteh@ucdavis.edu**

[2]**Department of Animal Science, University of California-Davis, Davis CA 95616**

There is a high degree of certainty that Sacramento splittail (*Pogonichthys macrolepidotus*) populations are adversely affected by exposure to contaminants in the environment. However, investigations to detect and quantify chronic sublethal responses in splittail that are attributable to contaminants are lacking. This study evaluated the sublethal effects of splittail larvae (7-day post hatching) exposed to field water samples contaminated with esfenvalerate and diazinon. Four hundred splittail (10 per replicate and four replicates per treatment) were exposed to the field water samples using the United States Environmental Protection Agency standard static renewal method (EPA-600-4-91-002 7/1994) for acute toxicity testing. Exposure lasted 96 hours. After the exposure, mortality was recorded and fish were transferred and raised in clean well water at 18 °C for three months. Concentrations of field samples for esfenvalerate and diazinon were verified analytically. At the end of the experiment, cumulative mortality was determined, and individual fish were weighed, measured to determine condition index and processed for biochemical and histopathological analyses. Results from this study will be reported.

RESTORATION OF FLOODPLAIN AND RIPARIAN FORESTS AT LEVEE BREACHES

Wendy B. Trowbridge*, J.L. Florsheim, and J.F. Mount

Environmental Science and Policy, University of California, Davis, 1 Shields Ave., Davis, CA 95616
Phone: 530-754-9133, e-mail: wbtrowbridge@ucdavis.edu

Successful restoration of floodplain and riparian habitat throughout the Central Valley depends on a thorough understanding of the physical processes that historically created and destroyed floodplain forests. Prior to the construction of high levees in late 1800s and early 1900s, the Cosumnes River was an anastomosing system of multiple active and abandoned channels, lakes and marshes. The constant creation of new channels destroyed old habitat and created new surfaces where flood adapted trees could establish. The Nature Conservancy has created a natural experiment to mimic this process by breaching the levees on its Cosumnes River Preserve. There are two main levee breaches, one created in 1995 and one in 1997. These breaches created diverse topographic features by delivering large quantities of sand onto formerly flat agricultural fields.

We are studying how these features impact establishment, survival and growth rate of cottonwoods (*Populus fremontii*) and willows (*Salix* sp.). In the first two years after the breaches were created floods carried large volumes of sand and debris out onto the new floodplain. Patches of trees then sprouted vegetatively from the debris. There was some establishment from seed but these trees are at lower elevations away from the sand splays and experience high mortality and low growth rates. Patch density and growth rate are positively correlated with the depth of the surrounding sand deposit. After the main sand splay was built there was less widespread deposition and no additional establishment. These preliminary results suggest that levee breaches should be created to deliver as much sand as possible in their first two years to create a large healthy floodplain forest.

TOXICITY OF DORMANT SPRAY PESTICIDE RUNOFF FROM CALIFORNIA ORCHARDS

Inge Werner[1], L.A. Deanovic, D.E. Hinton, J.D. Henderson, G.H. Oliveira, B.W. Wilson, B.T. Angermann, W.W. Wallender, P. Osterli, W. Krueger, M.N. Oliver, and F.G. Zalom

[1]**University of California, Davis, 1 Shields Avenue, Davis, CA 95616**
Phone: 530-754-8060, Fax: 530-752-9692, e-mail: iwerner@ucdavis.edu

Organophosphorous (OP) insecticides, especially diazinon and chlorpyrifos, have been routinely detected in surface waters of the Sacramento and San Joaquin River watersheds, coincident with storm events following their application to dormant orchards during the winter months. As a preventive best management practice (BMP), OP pesticides are increasingly replaced by more hydrophobic pyrethroid pesticides such as Asana (esfenvalerate). In addition, various types of ground cover vegetation can potentially increase the soil's capacity for water infiltration, thus preventing storm runoff from orchards. To measure the effectiveness of these BMPs, storm runoff was collected in the Artois prune orchard (Glenn County, CA) during a February 2000 rain storm, 4 days after two insecticides (Diazinon, Asana) were applied to different orchard sections. Bare soil and 3 different cover crops were tested for their effect on runoff (see poster by Angermann et al.) and toxicity. Water samples were chemically analyzed. Acute toxicity was tested by exposing larval fathead minnows (*Pimephales promelas*), larval Sacramento splittail (Pogonichthys macrolepidotus), and water flea (*Ceriodaphnea dubia*) to the field water samples using the U.S. EPA standard static renewal method (EPA-600-4-91-002 7/1994). Mortality was recorded after 96 hours for fathead minnows and Sacramento splittail, and after 48 hours for water flea. Results of chemical analysis and toxicity testing will be presented. Supported in part by CALFED contract #B-81609.

EVALUATION OF MITTEN CRAB EXCLUSION TECHNOLOGY AT THE TRACY FISH COLLECTION FACILITY, SOUTH DELTA

Robert G. White[*1], B. Mefford[2], C. Liston[3], L. Hess[4], B. Bridges[5]

[1]**Bureau of Reclamation, Fisheries Applications Research Group, Denver, and U.S. Geological Survey, Cooperative Fisheries Research Unit, Montana State University, Bozeman, MT 59717, Phone: 406 994-4549, Fax: 406 994-7479, e-mail: bigskyelk@aol.com**

[2]**Bureau of Reclamation, Water Resources Research Laboratory (D-8560), Denver, CO, 80225**

[3]**Bureau of Reclamation, Division of Resources Management (MP-400), Sacramento, CA 95825**

[4]**Bureau of Reclamation, Fisheries Applications Research Group (D-8290), Denver, CO, 80225**

[5]**Bureau of Reclamation, Tracy Project Office, Byron, CA 94514**

The large mitten crab invasions of the south Delta in the late 1990s impacted negatively the State and federal fish salvage facilities. Crabs accumulated in many parts of the facilities, especially the holding and transport tanks, killing many fish. New techniques for separating and removing crabs from fish were rapidly developed and evaluated by the Bureau of Reclamation. At Tracy, a vertical traveling screen was operated and tested during September 19 through October 14, 1999. Objectives were to determine the efficiency of crab removal and any effects on fish passage. Forty two evaluations each consisting of 3-10 minute periods when crab removal and fish passage were quantified were made during both day and night. Crab removal efficiency was 90%, with no effect on fish passage. Of 33,341 fish sampled (25 species), only three of ESA concern were encountered (splittail). Most fish passed through the screen successfully, although 16 (all 200 mm) were removed by the screen during tests. Minor modifications will be made to the screen and collecting system for 2000 evaluations. We conclude that these methods for crab removal are efficient and fish friendly, and can be applied to existing and future CALFED fish facilities in the south Delta.

FLOODPLAIN ACQUISITION IN THE COSUMNES RIVER CORRIDOR

Keith E. Whitener* and B. Waegell

The Nature Conservancy, 13501 Franklin Blvd., Galt, CA 95632
Phone: 916 683-1767, Fax: 916 683-1702, e-mail: kwhitener@cosumnes.org

The Nature Conservancy (TNC), recognizing the value of the riparian habitat along the Cosumnes River and the potential for restoration, began protecting lands along the Cosumnes River floodplain in 1985. In 1995, TNC began its first attempts at floodplain restoration through the use of natural processes. Two planned levee breeches resulting in the reconnection of approximately 600 acres of previously farmed land to its floodplain have shown many benefits: natural reforestation, utilization of aquatic habitat by priority fish species, and increases in freshwater seasonal wetlands. As a result of this initial success and an increasing understanding of the importance of maintaining natural flood patterns along the Cosumnes, TNC applied for and received three separate CALFED grants for the acquisition and initial land management of additional floodplain properties along the Cosumnes River. To date, five properties totaling approximately 2,550 acres have been purchased and one 300-acre property has been optioned using CALFED funding. These properties include approximately six river miles of floodplain and associated riparian forest habitat as well as seasonal and permanent wetlands. Initial land management has included baseline biological surveys, archeological surveys and infrastructure cleanup and removal. These initial activities will help TNC determine future land management activities including levee removal, restoration activities and long-term management objectives.

OPTIMIZATION OF CHOLINESTERASE ASSAYS TO STUDY EXPOSURE OF FISH TISSUES TO ORGANOPHOSPHATE PESTICIDES AND OTHER AGROCHEMICALS

B.W. Wilson[*1], J.A. Whitehead[2], A. Ramirez[1], J.D. Henderson[1], S. Henson[1], and S.L. Anderson[2]

[1]**Dept. of Animal Science and Dept. of Environmental Toxicology, 1 Shields Ave., University of California, Davis, CA 95616, Phone: 530-752-3519, Fax: 530-752-0175, e-mail: bwwilson@ucdavis.edu**

[2]**Bodega Marine Laboratory, University of California, Davis, Bodega Bay, CA 94923**

Since WWII organophosphates (OPs) and other pesticide neurotoxicants have been applied to California farms, fields and orchards. Recent episodes of OP runoff into the watershed of the Central Valley have raised concerns about their effects on water quality and possible ecotoxic and genotoxic damage to aquatic species. Such exposures also serve as sentinels of human and ecosystem health. OP inhibited cholinesterase enzymes (ChEs), especially acetylcholinesterase (AChE), are important regulators of neurotransmission. AChE levels in brain, muscle and other tissues of selected fish species are being used as biomarkers of exposure and effect in the EPA-funded study "Genetic Diversity of California Native Fish Exposed to Pesticides." There are no agreed upon standard conditions for ChE determinations in fish (or in other species including the human). Studies of ChE activity, localization and molecular forms are underway. Here we report research to optimize the assays for several species including the Sacramento sucker (*Catastomas occidentalis*), steelhead (*Oncorhynchus mykiss stonei*), and rainbow trout (*Onchorynchus mykiss*). Brain and other tissues from fresh caught sucker and steelhead, and from captive raised rainbow trout were stored frozen at -70oC until use and homogenized in Triton X-100, PO4 buffer. Samples were assayed at ascending concentrations of the substrate acetylthiocholine and selected inhibitors (BW 284c51 for AChE and iso-OMPA for non-specific BChEs) using a modification of the Ellman colorimetric assay to establish the optimum substrate concentration and the identity of the enzymes concerned. The results to date show: the major activity in brain, muscle and gill behaves like AChE; muscle AChE activity in the Sacramento sucker was relatively high compared to brain on a per weight basis. In general, acetylthiocholine concentrations of 2-3 mM seem optimal for routine determinations. (Support: EPA Star Grant 98-NCERQA-D1; rainbow trout courtesy of Dr. Silas Hung, Department of Animal Science).

PHYSIOLOGICAL STRESS RESPONSES OF YOUNG SPLITTAIL EXPOSED TO A SIMULATED FISH SCREEN

Paciencia S. Young*, C. Swanson, M.L. Danley, S.N. Chun, N.J. West, V. Afentoulis, and J.J. Cech, Jr.

Wildlife, Fish, and Conservation Biology, University of California, 1 Shields Ave., Davis, CA 95616
Phone: 530-754-4398, Fax: 530-752-4154, e-mail: psyoung@ucdavis.edu

Juvenile splittail (Pogonichthys macrolepidotus), a threatened native species of the Sacramento-San Joaquin Delta system, may be vulnerable to 2,000 water diversions distributed throughout the Delta. Fish screen installation has been identified as one activity that would reduce direct mortality associated with water diversions. However, no studies have been conducted on sublethal stress responses of fish exposed to fish screen. We quantified the physiological stress responses of young-of-the-year splittail after exposure to a simulated fish screen at different approach and sweeping flow combinations and at two temperatures. Fish (20 per group; standard length: 6-8 cm) were exposed to a circular 3-m diameter wedge-wire fish screen with 2.3 mm vertical bar spacing in a 0.67-m wide test channel (Fish Treadmill) for 2 h during the day under ten combinations of approach (range: 0-15 cm/s) and sweeping range: 0-62 cm/s) flows at two temperatures (12 and 19°C), with three replicates per treatment, and bled during recovery. Our results showed that splittail plasma cortisol, lactate and glucose levels in both temperatures generally increased above resting levels immediately after exposure to the fish screen at any flow combination indicating that exposure to the fish screen may have been stressful to fish. These responses peaked at 0.5 h post-experiment, possibly due to fish collection after the experiment. Physiological parameters gradually returned to resting levels 24 to 48 h after exposure. None of the physiological responses immediately after the exposure correlated with screen contact rates, swimming velocity, or injuries. However, plasma cortisol, glucose, and blood hematocrit levels were significantly higher at 19 than at 12°C indicating greater physiological stress responses associated with higher temperature. This study was supported by DWR, CDFG, USBR, and CALFED.

DORMANT SPRAY ALTERNATIVES CALCULATOR

Frank G. Zalom[*1], M.N. Oliver[2], J.F. Strand[1], A. Corbett[1], D.E. Hinton[3], and K. Klonsky[3]

[1]**Statewide Integrated Pest Management Project, University of California, 1 Shields Ave., Davis, CA 95616, Phone: 530-752-8350, Fax: 530-752-6004, e-mail: fgzalom@ucdavis.edu**

[2]**University of California Cooperative Extension, 3800 Cornucopia Way, Suite A, Modesto, CA 95358**

[3]**University of California, 1 Shields Ave., Davis, CA 95616**

Organophosphate pesticides, especially diazinon and chlorpyrifos, have been detected in the Sacramento and San Joaquin River watersheds coincident with storm events which follow their application to dormant orchards; levels have been of sufficient magnitude and duration to violate the Central Valley Water Quality Control Board Basin Plan water quality standard for toxicity. Dormant organophosphate and oil sprays have been used for many years, and have been the preferred method of control for the target pest complex. University of California researchers have identified alternatives for most of the key pests controlled by dormant sprays. However, the viable options are more complicated to use, less familiar to growers, require careful monitoring, and often require more than one distinct action to achieve a similar level of pest control.

A calculator was developed to identify potential costs associated with viable options to the dormant spray, a major concern for growers. Input variables relate directly to control of the target pests, and include: monitoring cost; number of applications and cost of alternative pesticide(s) that would be used to control the target pests during the dormant season, during bloom, or in season; number of in season sprays over and above those normally applied; number of applications and cost of additional miticides used to control spider mites resulting from their not being targeted by dormant organophosphate and oil spray; and application method. Total cost for each option can vary by the per acre or per unit cost of the service or product utilized, rate of materials applied, and number of sprays, if any, based upon pest abundance as indicated by a monitoring program. The calculator is available on line at the UC Statewide IPM Project web site, http://www.ipm.ucdavis.edu. Supported in part by CALFED contract #B-81609.